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Analysis of Costs for Compliance with Federal Radiation Protection Guidance for Occupational Exposure. Volume 2: Case Study Analysis of the Impacts of Proposed Radiation Protection Guidance for Workers

Faucett (Jack) Associates, Inc., Chevy Chase, MD

Prepared for

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This report contains the writeups of case studies conducted in support of an effort to estimate costs and economic impacts of rpoposed Federal Radiation Protection Guidance for Occupational Exposures. The purpose of the case studies was to develop Background information on representative organizations necessary to determine the impact of the proposed guidelines on selected industries. This information was used, together with other data, to estimate the aggregate costs of compliance with the proposed guidelines. The cost estimates are contained in acompanion report.

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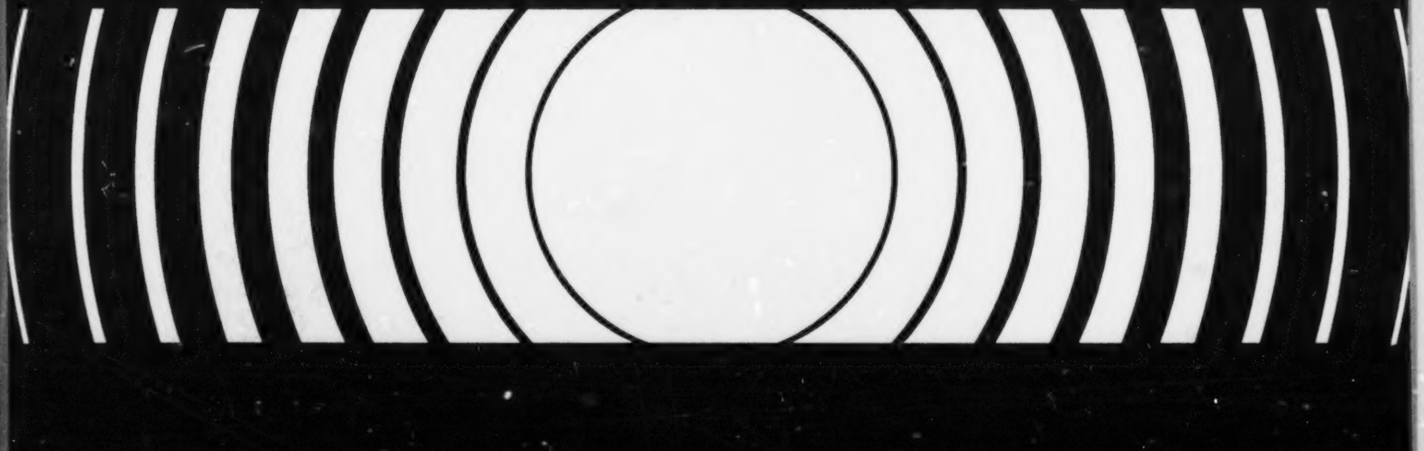

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EPA 520/1-83-013-2

Analysis of Costs for Compliance with Federal Radiation Protection Guidance for Occupational Exposure

(Proposed on January 23, 1981)

Volume II: Case Study Analysis of the Impacts of Proposed Radiation Protection Guidance for Workers

November 1983

Prepared under Contract No. 68-01-6486
by Jack Faucett Associates
Chevy Chase, Maryland
and
S. Cohen and Associates, Inc.
McLean, Virginia

Office of Radiation Programs
Environmental Protection Agency
Washington, D.C. 20460

i.a

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ACKNOWLEDGEMENT

This study of worker protection from ionizing radiation was directed by Michael F. Lawrence. Mr. Lawrence and Dr. Sanford Cohen of SC&A were co-principal investigators and conducted the case studies. Dr. Cohen is the principal author of the case study report and Mr. Lawrence is the principal author of the cost report. Mr. Charles Weaver participated in the case study of the Uranium mill and processing industry and prepared reports on that industry and the nuclear power industry. Mr. Gary Mathias assisted in the preparation of the cost report.

EPA technical direction for the project was provided by Andrew Leiter of the Office of Radiation Programs and valuable comments and recommendations were provided through the study by ORP staff including Allan Richardson, Byron Bunger and DeVaughn Nelson.

However, the strongest acknowledgement goes to the health physics professionals at each of the 27 establishments where case studies were conducted. In each case their full cooperation, spending time with the case study team and promptly reviewing the draft case study reports, made this study possible.

INTRODUCTION

This report contains the writeups of case studies conducted in support of an effort to estimate costs and economic impacts of proposed Federal Radiation Protection Guidance for Occupational Exposures.[1] A summary of the proposed guidelines, compared against the existing FRC (Federal Radiation Council) guidelines, is given in Exhibit 1. The circled numbers in the summary correspond to the order in which these items are discussed in the case study writeups. The case studies were conducted during the period November 1981 through January 1983. The purpose of the case studies was to develop background information on representative organizations necessary to determine the impact of the proposed guidelines on selected industries. This information was used, together with other data, to estimate the aggregate costs of compliance with the proposed guidelines. The cost estimates are contained in a companion report.[2]

The categories of organizations using sources of ionizing radiation, together with the numbers of case studies in each category, are given in Exhibit 2. The total number of case studies was constrained by the available budget to 24. The justification for the allocation of case studies among the 24 slots is discussed below.

Selection of the Case Studies

The case studies were selected in three parts. Initially, 15 private sector case studies were selected specifically to evaluate the impact of the proposed EPA guidelines. Then, two additional case studies were added to evaluate the impact of the EPA guidelines on Department of Energy Facilities. Finally, nine additional private sector case studies were chosen, primarily to evaluate the impact of preliminary revisions by the Nuclear Regulatory Commission to 10 CFR Part 20. The NRC case studies are contained in a separate report.[3] However, versions of these case studies directed toward the proposed EPA guidelines were drafted and are contained herein.

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[1] Federal Radiation Protection Guidance for Occupational Exposures; Proposed Recommendations, Request for Written Comments, and Public Hearings, U.S. Environmental Protection Agency, Federal Register, Vol. 46, No. 15, January 23, 1981.

[2] Cost of Compliance with Proposed Radiation Protection Guidance for Workers, Jack Faucett Associates, September 1983.

[3] Cost of Compliance with Occupational Exposure Revisions to 10 CFR 20, Jack Faucett Associates and SC&A, December 1982.

EXHIBIT 1

SUMMARY OF PROPOSED CHANGES IN OCCUPATIONAL RADIATION PROTECTION GUIDANCE

REQUIREMENT	FRC GUIDANCE	PROPOSED NEW GUIDANCE	INTERPRETIVE ASSUMPTIONS
Justification	"...no man-made radiation exposure without the expectation of benefit..."	"...occupational exposure should be justified by the net benefit ... include considerations of alternatives not requiring exposure."	No substantive change from current requirements; i.e., no new paperwork required.
ALARA	"...encourage maintenance of radiation doses as far below this guide as practicable."	"...assure that collective dose is ALARA." Also, maintain individual doses and lifetime doses ALARA.	No substantive change from current requirements; i.e., no new paperwork required.
RPG's			
W.B.			
Rate	∠3 rem/qtr.	① <5 rem/yr.[1]	The quarterly limit is eliminated.
Accumulated	∠5(N-18) limit, where N = age.	② <100 rem objective in lifetime.	Assume existing workers are grandfathered.
Internal Exposures	Individual critical organ limits carried out through MPC's (Radioactivity Concentration Guides)	⑧ $\Sigma w_i H_i < 5$ rem/yr., where H_i is annual dose equivalent and committed dose equiv.[2] to organ i, and: $w_{breast} = .2$ $w_{lung} = 0.16$ $w_{red\ bone\ marrow} = 0.16$ $w_{thyroid} = 0.04$ $w_{bone\ surfaces} = 0.03$ $w_{skin} = 0.01$ $w_{other\ organs} = 0.08$ Radioactivity Intake Factors (RIF's) calculated from the above.[3]	Note constraints from subsequent requirements on gonads and other organs. EPA will supply values of RIF's and corresponding MPC's, as in the Attachment.
Combined uniform W.B. and internal exposures.	Independent limits	W.B. + $\Sigma w_i H_i < 5$ rem/yr.	
Extremities and Individual Organs	Hands & forearms, feet & ankles < 25 rem/qtr. and ∠ 75 rem/yr.	Hands ∠ 50 rem/yr.	
	Head and trunk, active blood forming organs, gonads, or eye lens ∠3 rem/qtr.	③ Eye lens or gonads < 5 rem/yr.	Includes external exposure and committed dose equivalent[2] from internal.
	Skin of W.B. & thyroid < 10 rem/qtr. and ∠ 30 rem/yr.	Other organs < 30 rem/yr.	
	Bone < 0.1 μgm Ra-226 or equiv. body burden		
	Other organs < 5 rem/qtr. and 15 rem/yr.		

---

⑨ [1] As an alternative, consider W.B. RPG < 1.5 rem/yr.

[2] "Annual committed dose equivalent" means the sum of all dose equivalents that may accumulate over an individual's remaining lifetime (usually taken as 50 years) from radioactivity that is taken into the body in a given year.

[3] If any specific RIF is larger then currently in use, use current limit.

EXHIBIT 1

SUMMARY OF PROPOSED CHANGES IN OCCUPATIONAL RADIATION PROTECTION GUIDANCE
(Continued)

REQUIREMENT	FRC GUIDANCE	PROPOSED NEW GUIDANCE	INTERPRETIVE ASSUMPTIONS
Exposure of Minors	1/10 RPG's	1/10 RPG's	
Exposure of Unborn	No Guidance	⑦ Alternatives: i. Women voluntarily keep dose to unborn $<$ 0.5 rem during known/suspected pregnancy. ii. Women able to bear children voluntarily avoid jobs with dose $>$ 0.2 rem/mo., and keep dose to unborn $<$ 0.5 rem during known pregnancy. iii. Women able to bear children limited to jobs with dose $<$ 0.2 rem/mo. and dose to unborn $<$ 0.5 rem.	Requirement on the unborn is assumed to be met if satisfied by the woman.
Lower Limits	Permitted after consideration by agency.	Agencies may set limits below RPG's and RIF's when appropriate.	Assume RPG's in this guidance for purposes of cost estimate. If any future lower limits, the other regulatory agencies would justify them separately.
Higher Limits	Permitted after consideration by agency.	Permitted after consideration by agency (but must be publicly disclosed).	Assume RPG's in this guidance for purposes of cost estimate. If any future lower limits, the other regulatory agencies would justify them separately.
Training	No guidance	⑥ All radiation workers must be instructed on levels of risk from radiation and radiation protection principles.	Quantitative guidance on risk.
Monitoring	No guidance	Range A (assume <0.1 RPG): Monitor area exposure rates to assure exposures in range and ALARA.	Done once and for all unless changes in source and/or exposure configuration.
		⑤ Range B (assume ≥ 0.1 RPG and < 0.3 RPG): Monitor and record individual exposures.	Individual dosimeters and records.
		④ Range C (assume > 0.3 RPG and < 1.0 RPG): Monitor area exposure rates before and during tasks in addition to monitoring individual exposures.	Individual dosimeters and records plus surveys before and during tasks.
Supervision	No guidance	Range A (assume < 0.1 RPG): No requirements.	
		⑤ Range B (assume > 0.1 RPG and ≤ 0.3 RPG): Provide professional radiation protection supervision[4] sufficient to assure exposures justified and ALARA.	Assume radiation protection professional is available but not necessarily full-time. Also, assume no formal paperwork required.
		④ Range C (assume > 0.3 RPG and < 1.0 RPG): Provide professional radiation protection supervision[4] before and while tasks are undertaken which make significant contribution to exposures in this range and to assure exposures are ALARA.	Assume full-time radiation protection supervision. Exposure to the supervisor is not implied.

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[4] Assume that a "radiation protection professional" is a certified Health Physicist, Medical Physicist, or individual with equivalent training and experience.

EXHIBIT 2

CATEGORIES AND NUMBERS OF CASE STUDIES

CATEGORY	NUMBER
Hospitals	4
Medical Private Practice	2
Industrial Radiography	3
Manufacturing and Distribution	2
Fabricators of Light Water Reactor Fuel	2
Well Logger	1
Dentist	1
Department of Energy Facilities	2
Commercial Light Water Reactors	5
University Reactor	1
Uranium Mill	1
Uranium Conversion Facility	1
Nuclear Pharmacy	1

The initial 15 private sector case studies were selected on the basis of potential impact, drawing heavily from the 1975 EPA study of occupational exposures.[1] Impact was defined as the degree to which a particular industry might be affected by the proposed guidelines. Numbers of workers potentially exposed in excess of 5 rem was not considered to be a sufficient criterion, since the establishment of a 5 rem/year whole-body RPG is only one part of the proposed guidance. (Also, many of the alleged annual exposures in excess of 5 rem in the 1975 data base may be anomalous.)

The following were considered as possible indicators of impact:

1. Numbers of whole-body exposures in excess of 5 rem
2. Numbers of whole-body exposures in Range B (0.5-1.5 rem) and Range C (1.5-5 rem)
3. Numbers of females of child-bearing age with exposures in excess 0.5 rem
4. Numbers of organ exposures in excess of the proposed RPG's
5. Numbers of workers with measurable internal exposures

Cross-industry data were unavailable for items 4 and 5. Thus items 1 through 3 were used as the actual indicators of impact.[2]

Exhibit 3 presents items 1, 2, and 3 from the data given in the 1975 occupational exposure report, according to the "activity" categories given therein.[3] We observed that, aside from the Power Reactor Category, only the medical categories include significant numbers of exposures to females of child-bearing age. Noting this, we simplified the selection process by 1) discarding activities for which no exposures were

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[1] Occupational Exposure to Ionizing Radiation in the United States: A Comprehensive Summary for the Year 1975, U.S. Environmental Protection Agency, Office of Radiation Programs, EPA 520/4-80-001, November 1980.

[2] The estimates of female exposures were taken from a contractor report, Occupational Exposures to Ionizing Radiation within the United States for the Year 1975-A Statistical Data Base, prepared by Teknekron, Inc., under EPA Contract No. 68-01-1953, July 1978.

[3] 1.0 rem. rather than 1.5 rem, approximates the exposure separating Ranges B and C.

EXHIBIT 3

SUMMARY OF HIGH EXPOSURE DATA FROM 1975 SUMMARY

Activity	Estimated Total Number of Workers	Percent of Workers Exposed >5 rem	1.0-5.0 rem	0.5-1.0 rem	Percent of Females Ages 18-39 Exposed to >0.5 rem
1. Power Rectors	55,000	0.5%	12.8%	5.7%	16%
2. Industrial Radiography	20,000	0.4%	8.5%	6.4%	0%
3. Manufacturing & Distribution	11,000	0.5%	5.7%	4.2%	1%
4. Fuel Processing & Fabrication	11,000	0.7%	5.6%	5.9%	0%
5. Medical Hospital/ Clinics	100,000	0.2%	4.2%	5.6%	7%
6. Other Industrial	170,000	0.2%	3.5%	1.8%	1%
7. Veterinary	18,000	0.2%	1.1%	1.6%	3%
8. Medical Private	138,000	0.3%	2.5%	2.8%	4%
9. Waste Disposal	300	0.0%	0.0%	0.0%	No Data
10. Education	22,000	0.1%	1.5%	1.8%	2%
11. Dental	270,000	0.1%	0.5%	0.6%	1%
12. Podiatrists	10,000	0.0%	0.0%	0.0%	0%
13. Uranium Mills	300	0.0%	0.0%	0.0%	0%
14. Chiropractors	15,000	0.0%	0.2%	0.9%	No Data
15. Transportation	77,000	0.0%	0.2%	0.6%	No Data

recorded in excess of 5 rem, and 2) considering only exposures in excess of 0.5 rem and 5.0 rem. Thus, we estimated in each category the total number of workers exposed to radiation in excess of these limits and computed the percentage contributed to the total for each category. These results are given in Exhibit 4.

From the percentages given in Exhibit 4, a preliminary allocation of case studies was made. At the time, it was assumed that enough data existed in the open literature on power reactors so that a case study was unnecessary. Assuming 15 case studies for the remaining activities, the allocation of case studies to each activity is given by the following:

Activity	Potential Numbers of Case Studies
Industrial Radiography	~1
Manufacturing & Distribution	0-1
Fuel Processing & Fabrication	0-1
Medical Hospital/Clinic	2-4
Other Industrial	3-4
Veterinary	~0
Medical Private	4-3
Education	~0
Dental	3-1

Where a spread is indicated, the number on the left was determined from the exposures in excess of 5 rem, whereas the number on the right was derived from the exposures over 0.5 rem.

Additional decision rules were used to select the final numbers of case studies for each activity. We placed more emphasis on the results based on exposures in excess of 0.5 rem because of the belief that many of the measured exposures in excess of 5 rem are anomalous and because it was assumed that the cost impact from the 5 rem RPG would not constitute a significant fraction of the costs of compliance.

It was necessary to further disaggregate the "other industrial" category into industry sectors. This category is complex; it contains exposures from the industrial use of electronic machines, as well as exposures from radionuclides licensed by the Agreement States used for industrial radiography and manufacturing & distribution.

EXHIBIT 4

ESTIMATED NUMBERS AND PERCENTAGES OF WORKERS EXPOSED TO HIGH AND LOW DOSAGES, BY ACTIVITY

	Estimated Workers >5 rem		Estimated Workers >0.5 rem	
Activity	Number of Workers	Percent of Total Exposed	Number of Workers	Percent of Total Exposed
1. Power Reactors*	300	*	10,000	*
2. Industrial Radiography	80	5%	3,100	8%
3. Manufacturing & Distribution	60	4%	1,100	3%
4. Fuel Processing & Fabrication	80	5%	1,300	4%
5. Medical Hospital/Clinic	200	14%	10,000	27%
6. Other Industry	300	20%	9,400	25%
7. Veterinary	40	3%	500	1%
8. Medical Private	400	27%	7,700	21%
9. Education	20	1%	700	2%
10. Dental	300	20%	3,200	9%
TOTAL (not including reactors)**	1,500	100%	37,000	100%

*Not included in totals shown below.

**Columns may not add to totals due to rounding

An NRC breakdown (by Program Codes) of the Other Industrial category is given in Exhibit 5 for those Program Codes containing significant numbers of monitored workers. Estimates are shown for the numbers of workers exposed in excess of 5 rem and 0.5 rem for the year 1978. From these data, it was determined that the only subcategory with significant numbers of workers exposed is that of well logging. Moreover, from a comparison of the numbers given in Exhibit 5 with those given in Exhibit 4 for the other activities, it was determined that well logging warrants only a single case study.

It was concluded that the exposures other than from well logging in the "other industrial" category are attributable to industrial radiography and manufacturing and distribution activities regulated by the states. Therefore, the numbers of case studies in the industrial radiography and manufacturing and distribution sectors were increased to three and two, respectively.

One other change from the preliminary numbers of case studies was deemed to be desirable. Because of the large number of case studies in the medical sector, and because of the frequent overlap between private practice and hospital practice, it was decided to reduce the number of medical private case studies from three to two. Correspondingly, the number of case studies in the fuel processing and fabrication sector was increased from one to two because of the interest in the impact of the internal exposure provisions of the proposed guidelines.

In order to adequately measure the impact of the proposed guidelines, at least one small firm in each of the industrial radiography, manufacturing and distribution, and fuel processing and fabrication sectors were examined.

The two Department of Energy facility case studies were selected by EPA. In making the selection, EPA placed considerable weight on the potential for internal exposures.

The nine additional case studies for NRC were selected for activities which were felt to be inadequately covered by the 15 initial case studies. The most obvious category was that of commercial power reactors. Because of the importance of this category to the NRC, five case studies were scheduled. Uranium milling and UF_6 conversion were added because a significant impact from the internal exposure provisions of both the proposed EPA guidelines and the revised 10 CFR Part 20 could be anticipated for these

EXHIBIT 5

DISAGGREGATION OF "OTHER INDUSTRIAL" CATEGORY OF LICENSEES

NRC Program Codes	Description	Total No.* Monitored	Estimated No.** Nationwide	Percent Workers* Exposed 5 rem (in 1978)	Estimated No. Exposed 5 rem	Percent Workers* Exposed 0.5 rem (in 1978)	Estimated No. Exposed 0.5 rem
03-110	Well Logging	5,044	13,000	0.2%	30	13.6%	1,800
03-120	Other Measuring Systems	17,553	49,000	0.01%	5	0.6%	300
03-510 & 520	Irradiators	2,894	7,000	0.0%	0	1.3%	90
03-710	Civil Defense	1,833	5,000	0.0%	0	0.2%	10
11-100 thru 500	All Source Materials	3,041	8,000	0.0%	0	6.5%	500
21-130 & 240 22-110 thru 200 23-100 & 200	Special Nuclear Material (not incl. Fuel Fabrication and Processing)	5,969	9,000	0.03%	3	2.0%	200

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*From Occupational Radiation Exposure; Eleventh Annual Report 1978, U.S. Nuclear Regulatory Commission, Office of Management and Program Analysis, NUREG-0593, January 1981.

**Obtained by correcting the Total No. Monitored for the fraction of licensees reporting, and doubling the corrected number to account for Agreement State licensees (assumed to be roughly comparable in number to the NRC licensees).

industries. A nuclear pharmacy was added because, during the hospital case studies it became apparent that a portion of the historic dose for this sector had been shifted to the nuclear pharmacies that were preparing unit dosages outside the hospitals. Finally, a university research reactor was added at the suggestion of NRC.

Conduct of the Case Studies

The case studies were conducted using the following step-wise procedure:

1. Initial Telephone Contacts

Candidates for the case studies were contacted by telephone to determine their appropriateness and willingness to be participants in the case studies. To determine the appropriateness, the following information was solicited:

- The nature of their business
- The number of badged employees
- Rough numbers of high exposures
- The potential for costs to their operations attributable to the guidelines (usually unknown, initially)

To determine the willingness, the following information was imparted:

- Short history of the FRC, the role of EPA, and the role of the regulatory agencies
- Short history of this rulemaking process
- Description of the tasks under the contract, including the numbers of case studies planned for each category
- The responsibilities of the participants in the case studies planned for each category

2. Confirmatory Telephone Contacts

Several followup telephone contacts were usually necessary to confirm the willingness of each candidate to participate in the case studies. At this time, potential schedule conflicts of the candidate were explored for the following two-month period so that an overall schedule could be developed for the interviews.

3. Scheduling of the Interviews

After the master schedule was developed, the candidates were contacted to confirm the dates for the interviews. A few iterations were necessary in some cases.

4. Confirmatory Letter

Confirmatory letters were sent to the participants giving the dates for the interviews and the nature of the information to be solicited. A copy of the Federal Register notice and the existing FRC guidelines were included, so that the participant could begin preparing for the interview. A sample letter is given in Exhibit 6.

5. Summary Information

Approximately 1 1/2 weeks before each interview, a packet of information was sent to the participant. This packet consisted of a cover letter (Exhibit 7), a summary of the proposed changes to the Guidelines (Exhibit 1), and a summary of the information to be obtained in the interview (Exhibit 8).

6. Conduct of the Interviews

The interviews were conducted on the premises of the participants. The discussions lasted for periods ranging from one-half to one working day. Two members of the project team, an engineer and an economist, were always present. The representative of the organization was generally the Radiation Safety Officer. Others present at the meetings ranged from company presidents to radiologic technicians. The discussions were informal, but directed. The first half of the discussions were designed to solicit general information about the organization, those items given in Part I of Exhibit 8. The second half addressed the impact of the proposed guidelines, using the summary in Exhibit 1 as a "road map". The provisions of the proposed guidelines were discussed in the order denoted by the circle numbers given in the margins of Exhibit 1.

EXHIBIT 6

Confirmatory Letter

Mr. Joe Doe
Radiation Safety Officer
XYZ Corporation
Address
City, State, Zip

Dear Mr. Doe:

Thank you for volunteering to assist us in estimating the costs of meeting the Environmental Protection Agency's proposed Federal Radiation Protection Guidance for Occupational Exposures. Jack Faucett Associates is currently under contract with EPA to conduct such cost estimates, and we are planning to synthesize industry-wide costs from the case studies conducted with you and other participants. In confirmation of our early telephone conversation, we expect to meet with you at time, date, at your facilities.

At that time, we hope to solicit from you information relating to your costs of meeting the provisions of the proposed Guidance, assuming that the Guidance is approved and promulgated in the form of regulation by the cognizant Federal agencies. We realize that these assumptions are speculative at this time, but they are necessary in order to collect the data which are necessary for cost-benefit type analyses.

Some public responses to the Federal Register notice have identified potential compliance costs such as increased training, education of staff, recordkeeping, badging, and/or monitoring. Additionally, the use of outside services (health physics support, assays, etc.), the hiring of additional staff, or the purchase of additional capital equipment might be involved. Finally, consideration should be given to the possibility of additional shielding and/or the revision of existing work practices.

I am enclosing a copy of the Federal register notice, along with the existing FRC guidance, for your convenience. Also, about a week before our scheduled discussions I will send to you a summary of the proposed guidance in a format convenient for discussions, with some clarifying commentary.

Dr. Cohen and I are looking forward to meeting you on date.

Sincerely,

Mike Lawrence
Jack Faucett Associates

Enclosure

EXHIBIT 7

Cover Letter with Summary Information

Mr. Joe Doe
Radiation Safety Officer
XYZ Corporation
Address
City, State Zip

Dear Mr. Doe:

In preparation for our discussions on date, I am enclosing two items. Attachment 1 is a summary of the proposed changes in the occupational radiation guidance. I hope that this format, which compares the proposed recommendations with the existing FRC guidance, and additionally provides some clarifying interpretive assumptions, is convenient for purposes of our discussions. Attachment 2 is a list of the information that we hope to obtain during our discussion.

We hope to keep our discussions as informal as possible. Dr. Cohen and I will represent Jack Faucett Associates. Although we hope to keep the meeting as small as possible, it might be helpful to include additional representatives from XYZ Corporation if they can assist us in estimating the costs of compliance with the Guidance.

For example, it might be necessary to include a particular engineer/technician (physician) if one of the recommendations would involve revised work practices and/or the acquisition of specialized equipment.

We are looking forward to seeing you at time, date.

Sincerely,

Mike Lawrence
Jack Faucett Associates

Enclosures

EXHIBIT 8

Information to be Obtained from the Case Studies

I. Description of the Firm

1. Products and/or services and markets, including estimate of total output
2. Jobs performed by radiation workers, and importance to overall operations
3. Employment - total and radiation workers
4. Labor costs (radiation workers vis-a-vis other workers)
5. Exposure distributions for each category of radiation worker
6. Existing radiation protection measures
    a. Training/education
    b. Badging/monitoring/assays
    c. Professional H. P. supervision
    d. Shielding
    e. Capital equipment
    f. Work practices

II. Costs of Compliance with Proposed Guidance

See Attached Incremental Cost Matrix

III. Impact on Firm

1. Increase in collective exposure
2. Effect on cost
3. Effect on level of service
4. Effect on level of output
5. Effect on prices
6. Effect on profitability
7. Effect on employment
8. Plant closure

EXHIBIT 8 (Continued)

INCREMENTAL COST MATRIX
PROVISIONS OF GUIDELINES

			RPG's						
Cost Item	Justification	**ALARA**	**W.B.**	**Internal**	Individual **Organs**	Exposure **of Unborn**	**Training**	**Monitoring**	**Supervision**
Training/Education									
Recordkeeping									
Badging									
Monitoring									
Outside Services									
Assays									
H.P. Services									
Additional Workers									
Capital Equipment									
Shielding									
Revised Work Practices									
Other									

7. Writeups of the Case Studies

With the exception of the Department of Energy facilities, the case studies were written up anonymously, as requested by some of the respondents. The information provided in the writeups follows the order of the discussions fairly closely. Initially, general descriptive material about the organization is presented. This is followed by discussions of the impact of the individual provisions of the guidelines, in the order given by the circled numbers in the margins of Exhibit 1.

8. Review of the Case Study Writeups

The initial drafts of the case study writeups were sent for review to the originating organizations.[1] In some cases, the writeups contained blanks reflecting gaps in the information. The respondents were asked to fill in the blanks, if possible, and to make changes in or corrections to any of the information contained in the writeups which incorrectly represented the facts or the organization's positions on specific issues. Typically, these changes were minor, and the reviews did not alter the descriptions of the impacts of the proposed guidelines contained in the initial drafts.

It is important to point out that the case studies largely reflect the organizations' views regarding the impact of the proposed guidelines on their organizations. These views were subjected to considerable discussion and, in some cases, attack during the course of the face-to-face meetings. Thus, these views, except where noted parenthetically in the writeups, appear credible to the authors of this report, at least insofar as spirited discussions could ascertain. However, the budget did not allow us to go into the field to directly monitor exposure rates, or to observe area work habits or procedures. This would have provided us with an additional degree of confidence in the results.

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[1] The case studies originally selected for NRC were not subjected to this additional review step. This is because these case study writeups were adaptations of case study writeups directed toward revisions to 10 CFR Part 20, which were subjected to reviews by the originating organizations. These case studies consisted of the 5 commercial light water reactors, the university reactor, the uranium mill, the uranium conversion facility, and the nuclear pharmacy.

A.1 LARGE HOSPITAL

This 650-bed hospital is located in an affluent suburb of a relatively large metropolitan area. The hospital is at full capacity (approximately 90% utilization), with no available beds for elective surgery at the time of the interview, and no further slots for affiliated physicians. The hospital employs approximately 2800 full-time employees, with roughly 375 of them monitored for radiation exposure.

Most of the hospital workers who are exposed to radiation work in the following four departments of the hospital.

i. Radiation Oncology

This department maintains two linear accelerators, a 6 MV and a 10 MV machine, both manufactured by Siemens. Although both machines are used primarily to produce bremmstrahlung photons, the 10 MV machine also is capable of producing 6, 8, 10, and 12 Mev electron beams. Approximately 100 patients are treated with these machines daily. The department also administers brachytherapy, consisting largely of Cs-137 sources (usually 70 mg of radium equivalent). On the average, two to three procedures are performed each month.

The Radiation Oncology Department utilizes the services of one medical physicist, one dosimetrist, one engineering technician (to maintain the linear accelerators), three radiation oncologists (physicians), two nurses, eight technologists and four secretaries. The medical physicist is certified by the American Board of Radiology (he is the only full-time "radiation protection professional" in the hospital). He is also the Radiation Safety Officer in the hospital, and spends approximately 25% of his time in that capacity. Additionally, on the floor that houses the brachytherapy patients, approximately 30 nurses are potentially exposed to radiation.

Over the most recent 12-month period, approximately 80% of the personnel in the Radiation Oncology Department received exposures of less than 0.025 rem/yr. The medical physicist received the highest annual exposure, approximately 0.08 rem.

ii. Diagnostic Radiology

This department maintains two CAT scanners (one for the head and the other for the whole body) and 43 X-ray tube heads (two located at a remote facility). There are two special procedures' rooms, in which, for example, angiography is performed.

The department utilizes the services of 13 physicians and approximately 70 technologists. Several of the physicians also maintain radiology practices outside of the hospital, and only their exposures received in the hospital are under its administrative control.

Over the most recent 12-month period, approximately 50% of the personnel in the Diagnostic Radiology Department received exposures of less than 0.025 rem/yr. The remaining received an average annual exposure of approximately 0.15 rem. The maximum annual exposure was 0.5 rem, to a technologist.

iii. Nuclear Medicine

This department, which is administered by pathologists, is relatively small for a 650-bed hospital. It would be more more typical of a 250-bed facility. The number of radioimmuno-assays using Tc-99m is relatively high. Approximately 30 Xe-133 procedures are carried out monthly.

The department utilizes the services of approximately five physicians and five to seven technologists. The physicians also maintain outside practices, and only their exposures within the hospital are under its administrative control. For their outside practices, the physicians have separate licenses with the NRC.

Over the most recent 12-month period, approximately 55% of the personnel in nuclear medicine received exposures of less than 0.025 rem/yr. The remaining 45% received an annual whole-body exposure of approximately 0.1 - 0.3 rem. The maximum annual exposure was 0.33 rem.

Approximately two years ago, the department ceased production of Tc-99m dosages from an in-house molybdenum generator and went to an outside vendor. This reduced the exposures of in-house personnel by approximately 30%, on the average.

iv. Cardiac Catheterization Laboratory

This department is typical for a 650-bed hospital, although for the number of procedures, two rooms, rather than the one room at this hospital, would be available. Approximately 1,150 catheterizations were performed over the most recent 12-month period, and the work load is growing rapidly. The department utilizes the services of 10 physicians and approximately 31 technologists.

The exposures are derived in roughly equal amounts from the insertion of the catheter (under fluoroscopy) and from the filming after the dye is injected (30 frames per second). Over the most recent 12-month period, 40% of the technicians in the cardiac laboratory received less than 0.025 rem; the remaining 60% received an annual whole-body exposure of approximately 0.2 rem, with a maximum of approximately 0.5 rem. For the physicians, the average annual exposure was 1.9 rem, and the maximum was approximately 3.2 rem. The busiest of the physicians (3.4 procedures per week) appeared to be receiving less exposure per procedure than the others (the minimum frequency of procedures was 0.65 per week).

v. Operating Room and Coronary Care Recovery Room

The only sources of exposure in the operating and recovery rooms are portable X-ray machines which are occasionally used during surgery. Additionally, there is a permanent fluoroscopy unit in coronary care. Approximately 100 personnel of the operating room staff, an additional 30 in anaesthesiology, and roughly 30 in coronary care are potentially exposed. Of these, less than 5% received measurable exposures over the most recent 12-month period. The maximum annual exposure was approximately 0.2 rem.

Each of the two rooms which house the linear accelerators are shielded with several feet of concrete. The diagnostic radiology rooms, the cardiac catheterization laboratory, and the hot lab in the Nuclear Medicine Department are shielded with lead wall liners. Special venting is installed in the laboratory in which xenon inhalation procedures are carried out. For those occasions in which brachytherapy is carried out, the patient is confined to his own room.

Prior to the consolidation of radiation safety under the medical physicist approximately 1½ years ago, each department had its own individual monitoring policy and contracted separately for dosimeters. Although dosimetry is now centralized, the dosimetry policy is still relatively "ad hoc". The attempt is to monitor all potentially exposed personnel, resulting in roughly 375 monitored individuals. However, some of the maintenance personnel, nursing staff, and clerical personnel who could possibly be exposed are not monitored. The current policy with respect to these personnel is to issue them dosimeters if they request them and if the Radiation Safety Officer judges that it would be consistent with the ALARA philosophy.

A uniform training program has been in effect for approximately a year, ever since the radiological technician was hired. Prior to that, each department was responsible for its own training program. The Diagnostic Radiology and Nuclear Medicine Departments used outside consultants for their radiation physics needs, and these consultants did training on an "ad hoc" basis. The current program provides one hour of training annually for the personnel of each department. This training program includes instruction on levels of risk. In this connection, the NRC material (Appendix to Regulatory Guide 8.29) and the writings of Bernard Cohen (in the Health Physics Journal) have been particularly helpful.

The current salary range for diagnostic radiology technologists in the area in which this hospital is located is $14,000 to $15,000 per year. The corresponding salary range for cardio-vascular technologists is $16,000 to $17,000 per year. The salary range for a Board-certified medical physicist is $35,000 to $45,000 per year. A radiologic technician earns $18,000 to $20,000 annually. Fringe benefits amount to an additional 30 - 40 percent of base salary.

1. Impact of Reduction in W.B. RPG

The change in the allowable annual whole-body exposure from 3 rem/qtr. to 5 rem/yr. is expected to have no impact in this hospital. The hospital has been living within the 5 rem limit for some time. There were no exposures over the most recent 12-month period in excess of 5 rem. One physician in the cardiac catheterization laboratory received an annual exposure of 3.2 rem; this was the highest annual exposure on record. The average physician exposure in this department was 1.9 rem. Therefore, even if the individual physician case load were to double or treble, the proposed limit should entail no additional costs.

2. Impact of Reduction in Accumulated Exposure Limit

This limit could have an impact on physicians in the cardiac catheterization laboratory. As can be surmised from the discussion given in the previous paragraph, it is likely that heavy case-load physicians in the not-too-distant future will be pushing up against the 5 rem annual RPG. Moreover, nothing can be done with existing technology or alterations in work practices to reduce the existing exposure per procedure. Under the proposed 100 rem lifetime limit, these physicians would have a 20-year horizon on their practices. The impact could well be a refusal on the part of certain physicians to wear their dosimeters.

The problem, however, may be artificial. The actual whole-body doses to these physicians are considerably lower than the readings on the film badges, since the badges are worn external to the lead-impregnated aprons (at the collar level) and aprons are consistently worn. If the badges were worn under the apron, the facility would be in violation of state regulations. Therefore, either the state regulations would have to be revised or an additional dosimeter would have to be worn under the apron. (This assumes that the state would honor the reading of the under-the-apron badge for purposes of compliance with this proposed guideline).

The current cost of film badges is approximately $.80/mo./badge. The administration of the personnel dosimetry program occupies approximately 20% of the time of the radiologic technician.

Although the problem is apparent in the case of the cardiac catheterization physicians, it may also be present, but hidden, in the case of the diagnostic radiology physicians. These physicians may be pushing up against the proposed RPG without it showing up on their film badges. This is because they may obtain a significant exposure in their private practices outside the administrative control of the hospital, and/or they do not consistently wear their film badges at the hospital.

This example highlights the problem in dealing with the existing 5(N-18) accumulated exposure limit. When exposure records are sent for, there exists limited confidence that these records incorporate exposures from previous employment. Therefore, the existing guidance is not enforced; how will the proposed guidance be enforced?!

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Only the exposure limit on the eye lens may cause a problem. In the last quarter of 1979, a study was performed to determine the exposure to the eye lenses of physicians in cardiac catheterization. (There could also be a problem with physicians in diagnostic radiology, but no data exist.) TLD's taped to the rims of spectacles revealed a "high average" of approximately 0.115 rem/month. Although this result would not appear to pose a problem, the current case load is approximately 50% higher than when the study was performed, and it is increasing at a rapid rate. Therefore, if the individual case load were to increase significantly, eye lens exposures could approach the 5 rem limit.

There are two technological fixes. A hood with a leaded acrylic shield is marketed but it is unacceptable because it cuts down on mobility. Lead impregnated eyeglasses are significantly preferable, although there would be a lot of resistance to wearing them, particularly amongst those physicians who do not currently wear eyeglasses. Each pair of these prescription eyeglasses costs approximately $400.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

The guidance would require supervision in the cardiac catheterization laboratory (as discussed earlier, a typical 650-bed hospital would have two such laboratories) and in the two special procedures' rooms of diagnostic radiology. (These two rooms are adjacent to one another).

This hospital has one full-time "radiation protection professional" (a Board-certified medical physicist), and he is occupied 75% of his time in the Radiation Oncology Department. Few of the physicians in the Diagnostic Radiology or Cardiac Catheterization Departments know how to properly use a radiation survey meter.

If supervision of these areas required the presence of a radiation protection professional, at least two additional medical physicists or health physicists would have to be added to the staff. A possible alternative would be to enhance the training of physicians potentially involved in these procedures in the areas of radiation physics and radiation protection principles.

The requirement of off-shift work is an additional consideration. The cardiac catheterization laboratory is routinely scheduled for 11 hours per day, on the average. Additionally, unscheduled usage of this room or the special procedures' rooms occurs, on the average, seven to eight times per week. Thus, the "radiation protection professionals" would have to be willing to be "on call" at odd hours of the night. Physicians handle this by working in teams.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

This guidance requires individual dosimeters and records and the availability of a "radiation protection professional." The hospital currently has both, so there would be no costs of compliance.

However, it was estimated that only approximately 10% of all hospitals have established such a program. Therefore, a retrospective examination of the costs of establishing this program may be helpful. To establish the radiation protection program as it currently exists required approximately 25% of the time of the medical physicist during his first year. Thereafter, approximately 10% of the medical physicist's time is required to maintain the program. Additionally, approximately 50% of the time of a radiologic technician is required.

An outside consultant could substitute for the medical physicist, if a full-time medical physicist were not in the employ of the hospital. However, it is unlikely that this would be as cost-effective, as long as a large percentage of the medical physicist's time could be picked up by mainstream hospital activities.

6. Impact of Training Requirements

The question associated with this guideline is the definition of a "radiation worker." At present, approximately 375 personnel are routinely monitored by the hospital. A training program, including quantitative guidance on risk, is now in existence. As discussed earlier, this consists of one hour per year of formal training specifically tailored to each of five departments. Thus, there would be no costs at this facility to comply with the training guidance.

However, it was estimated that less than 5% of hospitals have formal training programs in radiation protection. Therefore, a retrospective examination of the costs of establishing this program may be helpful. It is estimated that approximately 30% of the time of the radiologic technician is occupied with training. They are currently developing a pamphlet to distribute to radiation workers which will discuss basic radiation protection principles as well as provide quantitative guidance or risk. A $400 video tape marketed by Radiation Management Corporation is useful in this regard. There is considerable demand for custom-tailored training packages.

7. Impact of the Guidance for Protection of the Unborn

The hospital is currently operating within the framework of Alternative a. This was instituted several years ago, and seems to work very well. If pregnant, a woman is allowed to remove herself from activities involving exposure to the unborn. In the Diagnostic Radiology Department, significant exposures can only be received in the special procedures' rooms. Roughly five women are currently pregnant in this department. The administration insists that pregnant women wear lead aprons and dosimeters under the aprons, and they are restricted from fluoroscopy and special procedures.

The administration of this hospital is wary of Alternative b, since it is felt that it has the potential of causing personnel problems. There is always the potential for monthly exposures in excess of 0.2 rem in the special procedures' room, even though only one individual in the Diagnostic Radiology Department received an exposure in excess of 0.2 rem in any one month over the recent 12-month period. The feeling is that the female employees who want to make trouble will take advantage of this guideline by taking the month off from the special procedures' room. It is felt that less than 2% of the personnel would use this guideline for mischievous purposes. The costs to the hospital of this provision are very difficult to quantify.

Of the 70 technologists, secretaries and engineers in the Diagnostic Radiology Department, approximately 65% are women, 90% of whom are in the childbearing age range. (Because of the physical exertion required, this job is only suitable for the young.) The only way to assure that exposures would be less than 0.2 rem per month would be to remove these women from duty in the special procedures' room. (According to the hospital management, it is possible to receive 0.2 rem in one month, although this rarely occurs.) It is estimated that during normal working hours, four to five technologists are needed to work special procedures. A similar problem exists in the Cardiac Catheterization and Nuclear Medicine Departments.

If faced with this restriction, the physicians (radiologists) would be "up in arms." It is very difficult to hire enough personnel (largely young women) for these jobs. Moreover, if the existing personnel were faced with removal from special procedures' duty, many of them would terminate. (Apparently, this is the most interesting and challenging aspect of these jobs.)

8. Impact of Internal Exposure and Combined External Exposure Guidelines

The only department within the hospital with the potential for internal exposures is nuclear medicine. At present, with the exception of a portable air monitor calibrated to measure concentrations of Xe-133, there exists no program to measure internal exposures. It is felt that exposures are well within existing guidance, but there exists no empirical evidence to prove this assertion. Although the data from the portable air monitor have not been analyzed recently, the last time an analysis was performed, the results indicated that peak airborne concentrations were less than 25% of MPC. However, these concentrations are extremely time and spacially dependent, so that it is difficult to relate the measured concentrations to actual exposures.

Currently, nuclear medicine personnel handling radioiodine are monitored within the Nuclear Medicine Department using a clinical uptake probe. The hospital is considering the inception of a bioassay program for personnel handling radioiodine (I-125 and I-131) to be administered within the Radiation Safety Office. It is estimated that this will cost the hospital approximately $5,000 in capital equipment and roughly ten hours per month of a radiological technician.

The apparent prevailing philosophy with respect to internal exposures is that once the license application has been accepted by the NRC, and as long as there are no spills and the surfaces stay clean, there is no internal exposure problem. The burden of proof that there is an internal exposure problem then resides with the regulator. Hospitals are very rarely cited for internal exposure problems.

In light of the foregoing, it is difficult to estimate the costs to comply with the proposed EPA guidance. Admittedly, if an existing program were in place to quantitatively monitor internal exposures to demonstrate compliance with existing guidance, and if the internal exposures were indeed demonstrated to be as far below the limits as expected, then the costs to comply with the proposed guidance would be zero. However, the practical reality of the situation suggests that to demonstrate compliance with the proposed guidance, an internal exposure monitoring program would have to be instituted from scratch. It is estimated that this would involve the acquisition of approximately $10,000 of capital equipment (primarily a multi-channel analyzer) and would require part-time support of a radiologic technician (in possession of at least a B.S. in physics.)

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

It is estimated that this lower limit would "put the cardiac catheterization laboratory out of business." There is currently no way to lower the exposure per procedure. (Although the whole issue of monitoring exposure under the lead apron was not brought up again. If allowable, would this reveal an actual whole body dose an order of magnitude lower? If so, what is the problem with this reduced limit?) Also, the Inter-Society Commission for Heart Disease Resources has suggested a minimum frequency of procedures -- six per week -- for proficiency. At present, the busiest physician is performing, on the average, only 3.4 procedures per week. Thus, exposures will increase, rather than decrease, in the future.

Although this discussion has centered about the cardiac catheterization laboratory (because the individual exposures are known better), it is felt that a reduction in the RPG would also cause an insurmountable problem in the Diagnostic Radiology Department. Although the physician exposures in this department are poorly documented, it is felt that several of them are pushing the 5 rem limit, particularly if their outside exposures were added to the exposures received in the hospital.

A.2 LARGE TEACHING HOSPITAL

This 500-bed teaching hospital, located in the center of an urban area, is oversubscribed. The affiliation of the hospital with a medical school (approximately 500 students) influences the makeup of the radiation workforce and the nature of the tasks performed. For example, approximately one-half of the badged workers are potentially exposed to radiation in the course of the conduct of research programs at the medical school.

Personnel are potentially exposed to radiation in seven departments at the hospital. The only source of significant exposures, however, is the Department of Radiology, which is broken down into three divisions, as follows:

i. Nuclear Medicine

This Division houses six cameras, nuclear cardiology scanning equipment, and Radio-Immuno-Assay. Tc-99m (5 Ci generator) and Xe-133 dosages are prepared in a hot lab; the other compounds are now purchased from a nuclear pharmacy outside of the hospital. Approximately 150 scans are performed weekly. Personnel in the Division include two physicians, approximately ten technologists, five student technologists, and four residents. (The medical school offers a degree in medical technology which takes 1½ - 2 years to complete.) Approximately 20 personnel in the Division are provided with film badges. In 1980, the average whole-body dose in the Division was 0.85 rem. The maximum annual dose was 2.12 rem. Eight personnel received exposures in excess of 1.0 rem. Lead aprons are not worn in nuclear medicine.

ii. Diagnostic X-ray

This Division houses approximately 20 - 30 X-ray tubes and two CAT scanners (one for the head and the other for the whole body). Standard procedures are conducted at two sites, separated by a few city blocks (one site is an HMO). There are six special procedures' rooms located in a suite at the main hospital. Personnel in the Division include 12 physicians, approximately 50 - 60 technologists, and roughly 15 residents. Approximately 80 - 90 personnel in the Division are provided with badges. In 1980, the average whole-body dose in the Division was 0.48 rem. The maximum dose was 2.4 rem.

Eight personnel received exposures in excess of 1.0 rem. Badges are worn under the apron if eye protection is used, and over the apron if it is not (to indicate eye lens as well as W.B. dose).

iii. Radiation Oncology

This Division houses two linear accelerators, one portable skin therapy machine, and an X-ray machine used for simulation purposes (to establish a configuration for the Linacs). The Division includes two physicians, two physicists (both Board-certified), approximately ten technologists, four student technologists, and three residents. Overall, approximately 30 people in the Division are provided with film badges. The average external exposure in 1980 was 0.2 rem, whereas the maximum was 0.8 rem.

In addition to the the above Divisions, some research is also administered by the Department of Radiology, resulting in an additional 20 personnel who are provided with film badges. Moreover, the Radiation Safety Office (RSO) is administratively located in the Department of Radiology, although the Radiation Safety Officer is accountable to the hospital-wide Radiation Safety Committee. The RSO consists of the Radiation Safety Officer (Ph.D. in physics, not Board-certified), the Assistant Radiation Safety Officer (B.S. in physics), and two full-time technicians (non-degreed).

The second Department in which personnel are potentially exposed is the Department of Cardiology. This incorporates the cardiac catheterization laboratory, the stress laboratory (here, there is some overlap with the Division of Nuclear Medicine in the Department of Radiology), and the coronary care unit. Approximately 20 personnel are issued film badges in the Department of Cardiology. Most of the exposures are received in the cardiac catheterization laboratory, which is currently operating at the level of 500 procedures annually. In 1980, the average whole-body exposure in the Department of Cardiology was 0.3 rem; the maximum was 1.1 rem. Only two personnel received exposures in excess of 1.0 rem (all exposures measured under the apron).

The remainder of the potential exposures in the hospital are housed in the Operating Room (4 badges issued), the Department of Surgery (1 badge issued), Anaesthesiology (14 badges issued), Cystoscopy (16 badges issued), and the Physical Plant (6 badges issued). In 1980, the maximum exposure to individuals in these Departments was 0.4 rem.

As mentioned earlier, an additional couple of hundred film badges are issued to students, faculty members, and supporting staff members who are conducting research at the medical school. In 1980, these personnel received an average whole-body exposure of 0.5 rem. The maximum exposure was 0.4 rem. These individuals are included in the attached histogram of external exposures covering the entire facility for the year 1980. Of the 430 individuals issued film badges in 1980, only 45% received annual exposures in excess of 0.05 rem. Approximately 14% received exposures in excess of 0.5 rem, and 7% exceeded 1.0 rem.

The total employment at the hospital is approximately 2,800. The policy regarding personnel monitoring is as follows. Personnel who might be exposed to radiation in excess of 0.1 RPG (they are currently operating under a whole body RPG of 5.0 rem) are definitely issued film badges. An attempt is made to additionally monitor all those personnel who might potentially enter a controlled area in the course of their work. Finally, film badges are issued to each and every employee who requests one. Currently, close to 500 personnel are monitored. Film badges are processed monthly, although the RSO plans to go to a quarterly processing schedule in the near future.

The salary range for medical technologists is $10,000 to $20,000 annually, with a mean salary of approximately $15,000/year. The range of ages is typically 20 to 30, and most of the technologists are female. There is no premium for radiological technologists.

1. Impact of the Reduction in W.B. RPG

This hospital has in fact been operating within this limit for some time with no difficulty. There has not been a measured exposure in excess of 5.0 rem in recent memory. It is a policy of the hospital that affiliated physicians confine their practices to the hospital, and to the best of the knowledge of the RSO, this policy is followed. Therefore, the uncertainties in annual and accumulated exposures associated with outside practices are avoided. Some of the residents spend short periods of time at other institutions in the metropolitan area. However, when this occurs, they keep their film badges, and their exposures are under the administrative control of this institution.

It is unlikely that potential future increases in physician loads will result in a problem in maintaining exposures below this limit. It has been a policy at this facility to measure whole-body exposures under the lead apron if eye protection is available. (i.e., where it

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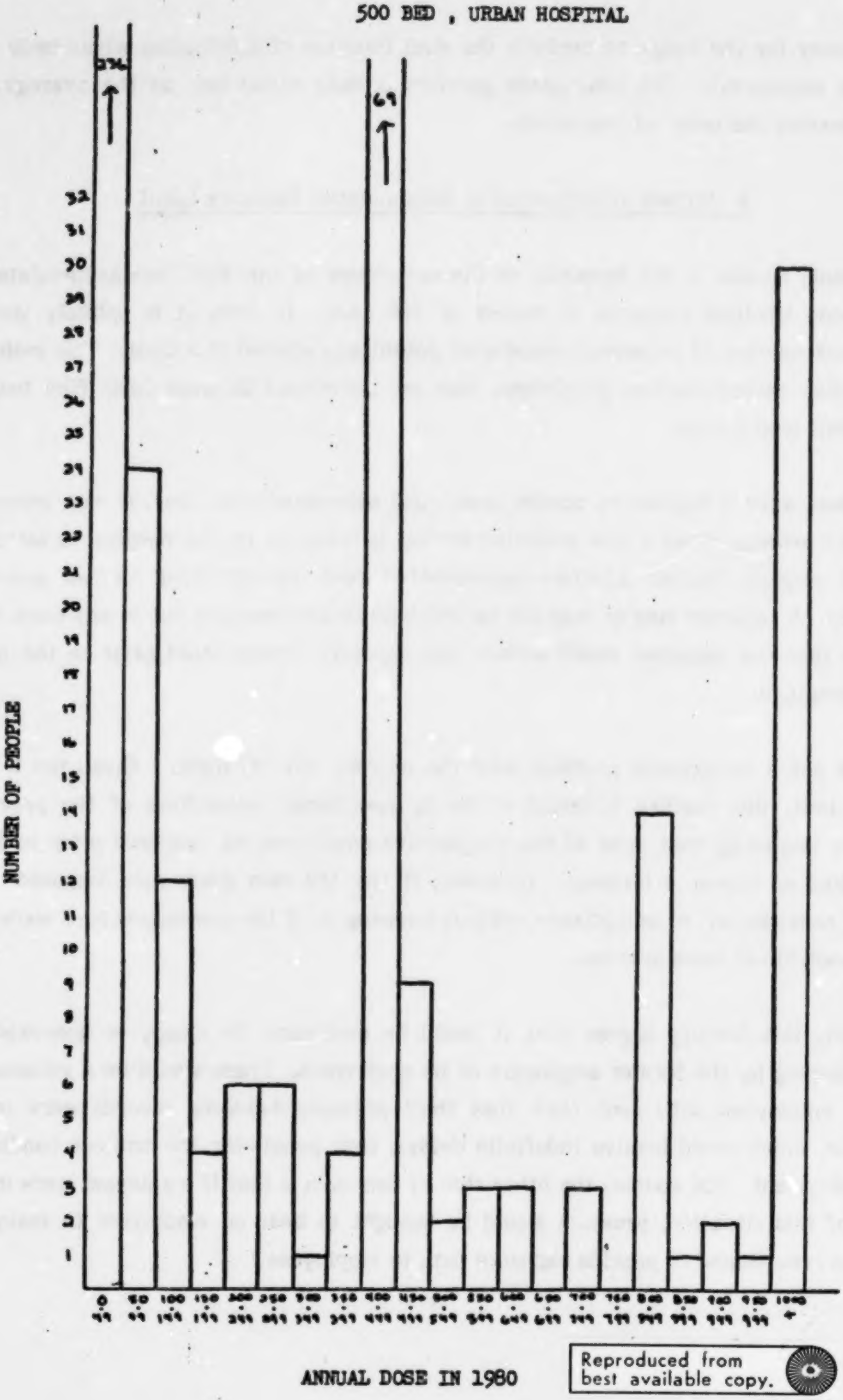

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is necessary for the badge to perform the dual function of monitoring whole-body and eye lens exposures). The lead apron provides a dose reduction, on the average, of approximately one order of magnitude.

2. Impact of Reduction in Accumulated Exposure Limit

At present, no one in the hospital, to the knowledge of the RSO, has accumulated a whole-body lifetime exposure in excess of 100 rem. In fact, it is unlikely that a significant number of personnel would ever potentially exceed this limit. This includes the cardiac catheterization physicians, who are permitted to wear their film badges under their lead aprons.

There does exist a regulatory burden (cost risk) associated with the 100 rem proposed limit. At present, when a new radiation worker is taken on by the hospital, a letter is sent to request his/her lifetime accumulated dose record from his/her previous employer. A response may or may not be obtained to this request; but in any case, it is unlikely that the response would include the exposure accumulated prior to the most recent employer.

There is not a compliance problem with the current 5(N-18) limit. Given the 5 rem annual limit, this facility is bound to be in compliance, regardless of the previous exposure (assuming that none of the prospective employees was exposed prior to 1960 and lacked an exposure history). However, if the 100 rem limit were imposed, this facility could be out of compliance without knowing it, if the previous record were not made available or were in error.

In effect, this facility argues that it could be penalized for sloppy or non-existent recordkeeping by the former employers of its employees. There would be a reluctance to hire employees until such time that their previous exposure records were made available, which could involve indefinite delays, thus penalizing the anxious candidate for employment. (Of course, the other side of this coin is that if employees were made aware of this situation, pressure would be brought to bear on employers to maintain accurate records and to provide exposure data to employees.)

3. Impact of the Proposed Guidance Relating to Extremities and Individual Organs

The 5 rem exposure limit on the eye lens and gonads would not pose a problem for this facility, since workers are currently abiding by this limit and have done so for some time. For those tasks in which high exposures to the eye are possible (i.e., cardiac catheterization), high attenuation spectacles are routinely worn. Although eye-level monitoring has not been performed, safe exposures have been assured by measuring the attenuation of test beams through the lenses of the spectacles.

This facility has discovered that it is not necessary to purchase expensive (i.e., $400 a pair), lead-impregnated spectacles from safety equipment suppliers. Apparently, high index-of-infraction lenses, available for the going price of regular glasses (i.e., $35 a pair) contain sufficient concentrations of high Z materials to provide beam attenuations comparable to lead impregnated glass.

As an aside, it was mentioned that nuclear medicine procedures (using Tc-99m, for example) may eventually replace a large fraction of the cine-mode procedures used in heart catheterizations. These have the added benefit of substantially reducing the exposure to both the patient and the workers.

The proposed exposure limits to the hands are probably not a problem. However, some concern was expressed about exposures to the hands of physicians during fluoroscopic examinations vis-a-vis existing guidelines. Potential exposures as high as 3 rem/minute are available in the direct beam, and several fluoroscopic procedures take several minutes. Yet the highest finger badges reading has been 1.5 rem/month, well within the proposed guidance on an annual basis.

The problem is that most of the physicians don't like to wear the finger badges, since they are alleged to reduce finger mobility. Since many physicians do not monitor their hands, exposures are unknown. Although there is no corroborative evidence, the RSO is uneasy about compliance in this area.

4. Impact of the Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Potential for exposures in this range exists in the Divisions of Nuclear Medicine and Diagnostic X-rays in the Department of Radiology, and in the cardiac catheterization laboratory in the Department of Cardiology.

The Division of Nuclear Medicine is housed in one long corridor with 12 rooms. Although the hot lab at the end of the corridor has the potential for the highest exposures, significant contributions to annual exposures in excess of 1.5 rem cannot be ruled out for any of the rooms along the corridor. Approximately eight people received exposures in excess of 1.0 rem in 1980.

The Division handles approximately 30 - 40 patients daily during one 10-hour shift. Surveys are carried out frequently by personnel from the RSO, but these personnel are based in a separate building. One individual on the floor would most likely satisfy the monitoring and supervision provisions imposed by this guideline. There are currently no medical physicists or health physicists permanently stationed on the floor. It might be argued that the two physicians and four residents are "equivalent" to "radiation protection professionals". However, it is unlikely that any of these individuals could currently pass the medical physics examination administered by the American Board of Radiology or American Association of Physicists in Medicine.

A similar situation exists in the Division of Diagnostic X-rays. Six special procedures' rooms are organized in a suite for a 10-hour, single shift operation. Here, however, two to three individuals would be required to cover all tasks significantly contributing to potential annual exposures in excess of 1.5 rem. Of course, one of the 12 physicians or 15 residents is always present in each of the rooms. Are these individuals equivalent to medical physicists? Probably not.

In the cardiac catheterization laboratory, which also operates on one scheduled shift, one supervisor would be sufficient. Here, however, the question of equivalency is moot! There are no radiologists among the physicians or residents; cardiologists are not likely to have the training or experience equivalent to medical physicists.

Emergency procedures are not unusual in all of the above areas. Thus, the supervisor would have to be on-call, just like the physicians and residents. If a number of them were required, the team concept could be applied. At present, the Radiation Protection Safety Officer and his assistant are frequently called in at odd hours to monitor unusual procedures.

5. Impact of the Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The hospital currently complies with this guidance. Approximately 500 workers are individually monitored, with all of the attendant recordkeeping. Frequent surveys are performed by the RSO, some of which are motivated by the NRC ALARA program. Although the Radiation Safety Officer is not Board-certified, he has a Ph.D. in physics with a specialty in nuclear medicine, incorporating several years of experience in two major medical institutions. Therefore, he has the equivalent training and experience of a medical physicist, and clearly is a "radiation protection professional".

6. Impact of Training Requirements

This institution has established an extensive training program in radiation protection which is administered by the RSO. Each radiation worker gets one hour of training annually, resulting in at least one course administered each week. Even the nurses, who are strictly speaking not radiation workers and are not routinely monitored (although they may request film badges and frequently do), are given 20-minute briefings because they may be exposed to implant patients.

The most extensive training course, involving two 2-hour lectures, is administered to individuals involved in research at the medical school. This course, instigated by the Radiation Safety Committee, must be passed (an examination is administered following the lecture series) before an individual is permitted to work with radiation sources in the conduct of research.

Only in the lectures for researchers are levels of risk quantified. At present, it is estimated that training activities occupy approximately 15% to 20% of the time of the Assistant Radiation Safety Officer. If levels of risks were to be presented in all of the radiation protection lectures, an additional 5% of the Assistant Radiation Safety Officer's time would be required, on the average.

7. Impact of the Guidance for Protection of the Unborn

The hospital has been operating under Alternative a for at least four years, and this has apparently worked satisfactorily. Four women are known by the RSO to be pregnant, and each of these has elected to be removed from tasks which might expose the unborn to a dose in excess of 0.5 rem. In three of the four cases, it was possible to shift the individuals' jobs within their Departments. In the fourth case, it was necessary to transfer the individual out of her Department (cardiac catheterization).

Considerable concern was expressed about Alternative b. It is possible to manage the known pregnancies, however it is felt that the "suspected" pregnancies might number in the hundreds. This Alternative could play havoc with the nursing supervisors. (As an aside, the new pregnancy test was discussed. Apparently, the HCG test is 98% accurate and is relatively inexpensive. If this or a similar pregnancy test were adopted, the test could possibly be worked into the resulting rule so as to prevent the self-serving use of this guidance.)

The promulgation of Alternative c would result in very strong objections from the physicians as well as the administrative staff of the hospital. In 1980, 4 - 5 individuals on the average, mostly in nuclear medicine, received monthly exposures in excess of 0.2 rem. It is estimated that at least 20 - 30 individuals (mostly females of child-bearing age) could potentially receive monthly exposures of this magnitude. If these individuals were to be removed from jobs with potential monthly exposures greater than 0.2 rem, they could not work in nuclear medicine, cardiac catheterization, or special procedures in diagnostic X-ray. These departments are very short of personnel. It would be very difficult to fill these 20 - 30 positions with males or non-fertile females. The labor pool does not exist because the pay is relatively low and there does not exist a career ladder.

8. Impact of Internal Exposure and Combined External Exposure Guidance

The policy with respect to monitoring for internal exposures varies from group to group. Much of the program focuses on radioiodine, since the current Radiation Safety Officer was hired four years ago to control a problem the hospital was experiencing at that time with radioiodine. Air monitoring (counting of charcoal filters) for radioiodine is now routinely carried out in the areas in which it is handled. (The only other air concentration measurements in the hospital are performed in the room in which Xe-133 is handled.) Assays are performed on anyone working with free iodine in excess of 500 μCi at a shot. Technologists involved in iodine therapy are encouraged to do an uptake count within 24 hours of potential exposure. Occasional checks are made of people who work with radio-immuno-assay. Once a month, routine thyroid uptake counts are made on everyone in nuclear medicine.

The proposed new MPC's based upon new models (Table B1 of EPA 520/4-81-003) do not appear to cause a problem at this hospital. However, the required procedure of combining the exposures to individual organs, as well as adding in the external exposure, would be a departure from existing practice. This is simply not done at the present time. It was agreed that this is implicit in the current guidelines, at least when one combines MPC's, but it is simply not routinely done. It was felt, however, that combining body burdens, or correspondingly, intake factors, is not implicit in the current guidance. In the case of body burdens, each organ is currently viewed independently.

Notwithstanding the foregoing and after quantitative evaluation of the estimated current internal uptake of radioisotopes at the hospital, it is not expected that the implementation of the proposed guidance would involve significant costs at this institution.

9. Impacts of the Reduction of the W.B. RPG to 1.5 Rem/year

In 1980, approximately 30 individuals, or 7% of those monitored (approximately 15% of those with measurable exposures), received whole-body exposures in excess of 1.0 rem. Most of these were in the Department of Radiology (only two in cardiac catheterization, where the film badge is routinely worn under the lead apron), and it is estimated that approximately 50% of them were physicians or residents.

It is felt that some of these higher exposures can be reduced by altering work practices. Rotation of personnel is already routinely carried out in the Division of Nuclear Medicine.

Although it is difficult to quantify, at least some additional personnel (probably not as many as 30) would have to be hired in order to comply with a reduced W.B. RPG. The collective dose would no doubt increase. Without conducting a detailed analysis, it was felt that the purchase of capital equipment to further reduce exposures would be more expensive than hiring additional personnel.

The difficulty in recruiting sufficient personnel to satisfy this hospital's current needs was discussed earlier in connection with the guidance relating to the unborn.

It should also be noted that this is a teaching hospital, so that some of the exposures, particularly to residents, may be higher than would be encountered in a non-educational environment.

A.3 MEDICAL CENTER

This medical center, located in the suburbs of a large metropolitan area, is affiliated with a major medical school. With approximately 500 beds in the hospital (almost always at full capacity), there are roughly 3,700 employees. Additionally, approximately 500 laboratories at the university (80% of them at the medical school), use licensed radioisotopes in research programs.

Most of the exposures to radiation occur in the Department of Radiology, which is comprised of three divisions. The Radiotherapy Division has three linear accelerators, two therapeutic X-ray machines (one of which is very low energy for superficial therapy), and three X-ray simulators (to set up patients for linear accelerator therapy). Approximately 70 people in this division are monitored for radiation exposure. Roughly 120 patients are treated daily with the linear accelerators. The Division additionally performs approximately 100 implants annually (primarily Cs-137, Ir-192 and I-125).

Approximately 200 employees are monitored in the second division of the Department of Radiology, Diagnostic Radiology. This Division operates 44 radiographic X-ray machines, 13 fluoroscopic X-ray machines, and four CAT scanners. Roughly 5,000 - 6,000 patients undergoing 6,000 - 7,000 examinations are seen monthly. The third division, Nuclear Medicine, performs approximately 350 scans monthly and monitors approximately 40 individuals.

The second department that uses ionizing radiation is Cardiology. With approximately 90 monitored employees, two radiographic and three flouroscopic X-ray machines are used in the cardiac catheterizations of approximately 200 patients, on the average, each month. Approximately 100 personnel in the Department of Nursing Services who may be exposed to patients undergoing brachytherapy are also monitored. Finally, approximately 600 - 700 individuals who conduct research in hundreds of laboratories at the University (approximately 80% at the medical center) are monitored.

The monitoring policy is to provide individual monitors to all technologists, dosimetrists, faculty, residents, and medical students (also, clerical workers in the Division of Nuclear Medicine) working in the Department of Radiology. Additionally, all personnel working in the cardiac catheterization laboratory are monitored. Nurses on floors with patients undergoing brachytherapy (with greater than 10 mg of radium equivalent), operating room nurses, and pediatric intensive care nurses (who may hold infants during radiographs) are also monitored. Also, technologists who conduct RIA's (in the Department of Pathology) are monitored. Every few years, clerical and maintenance personnel are monitored for a few months' period in order to confirm that their exposures are negligible. Monitoring is largely accomplished with film ($.45/badge/month), although the results are checked from time-to-time with TLD's (it is claimed that up to 20 mr/month of high energy photons may be missed with film at low doses).

Whole-body exposure distributions are given for 1980 in the attached Table. (Whole-body monitors are worn over the lead apron.) Only one individual received a dose in excess of 1.0 rem. The actual dose was approximately 3 rem to a technologist involved in brachytherapy. Most of the exposure was obtained during one incident in which the individual involved had not been fully trained. Thus the exposure was avoidable. For personnel involved in brachytherapy, digital dosimeters are routinely assigned, so that a real time estimate of exposures may be obtained. This has had a significant impact in lowering doses. The Table includes data on one of the many research groups which is monitored at the medical center. The exposure distribution for the Biochemistry Department is typical for this category.

A outside nuclear pharmacist is used to prepare most of the unit dosages for the Division of Nuclear Medicine. (A molybdenum generator is available to prepare emergency Tc-99m dosages.) Whole-body exposures to in-house nuclear medicine personnel did not decrease significantly after the hospital went to an external supplier. Rather, the whole-body exposures previously received when preparing unit dosages were traded off for exposures obtained from inspecting the shipments when they arrive from the supplier. Approximately 80% of the exposure obtained in nuclear medicine comes from imaging.

This facility has a substantial Radiation Safety Office (RSO). The Director has a Ph.D. in biophysics. Of the four to five professionals reporting to the Director, one has a Ph.D. in nuclear physics, another an M.S. in radiological physics, and the remainder bachelor's degrees in basic sciences. Although none of these professionals is certified in health physics, each of them has ten years or more of experience in the Office, and

WHOLE-BODY EXPOSURES FOR THE YEAR 1980
(Numbers of Individuals)

Exposure Range (rem)	Radiotherapy	Diagnostic Radiology	Nuclear Medicine	Cardiology	Biochemistry
Less than measurable	24	54	10	30	101
<0.10	25	63	9	23	1
0.10 - 0.25	4	23	4	9	0
0.25 - 0.50	1	9	0	3	0
0.50 - 1.00	0	3	0	4	0
>1.00	1	0	0	0	0

each could pass the certification examination with relatively little effort. Additionally, there are four to five technicians in the Office, one of whom with an advanced degree in physics. Two to three clerical personnel round out the office.

The level of staffers in the RSO has remained constant over the past 10 - 12 years. The current budget is approximately $450,000 per year. The range of salaries for the professionals is $27,000 to $42,000. The technicians earn from $15,000 to $27,000 annually. This is somewhat lower than the salaries of radiologic technologists, who earn between $20,000 and $30,000 annually.

In addition to this medical center, the RSO is also responsible for radiation protection at a VA hospital in the same community. This is also a teaching hospital affiliated with the same university. Although the VA hospital is larger (roughly 600 beds), it consumes less than 20% of the resources of the RSO. Finally, the RSO performs specialized consulting for two medical centers in adjacent communities (consuming less than 5% of its resources).

Other radiation professionals are available in the medical center. The Radiotheraphy Division directly employs five medical physicists; they are involved in therapy planning, not radiation safety per se. Two are faculty members and three are on the clinical staff.

With the exception of the radiologic technologists, board-certified radiologists, and nuclear medicine physicians, radiation workers at the medical center are required to satisfactorily complete a questionnaire with 50 questions on radiation protection before they are allowed to work with sources of ionizing radiation. Alternatively, they may take a five-hour course given monthly; the choice is made by their supervisors. If the individual fails the questionnaire, he or she is required to attend the formal course. The course includes a quantitative discussion on levels of risks. A new manual is being produced which will also cover levels of risk from radiation.

Radiologic technologists are exempt from the test because they must be registered by the state, which requires its own examination. (This state also requires radiological physicians to be registered.) Residents in radiotherapy are administered a formal four-hour course in radiation protection by the RSO. For new residents in nuclear medicine, a one-on-one discussion with an instructor from the RSO is held. Finally, nurses potentially exposed to patients undergoing brachytherapy are instructed on the principles of radiation safety by a member of the RSO at their work locations in the ward.

1. Impact of Reduction in W.B. RPG

The reduction in the allowable W.B. RPG from 3 rem/qtr. to 5 rem/yr. would have no impact at this medical center. The highest whole-body exposure over the past several years was 3 rem, received by a technologist involved in brachytherapy in the Division of Radiotherapy. However, as discussed earlier, this was more in the nature of an incident than a routine exposure.

2. Impact of Reduction in Accumulated Exposure Limit

The imposition of the proposed accumulated exposure limit would also have no impact at this facility. Some of the older physicists at the University have accumulated whole-body exposures in the range of 20 to 30 rem. The accumulated exposures of a few of the physicians are somewhat in excess of 10 rem. However, there are no accumulated exposures anywhere near 100 rem, and given the existing radiation protection program at this facility, there are not likely to be any near this level in the future.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

In 1980, one individual received an exposure to the hands of 20 rem. This was the same person who received an anomalous whole-body exposure of 3 rem. In general, individuals likely to receive significant hand exposures wear ring badges. In 1980, approximately 8% of those who were monitored for whole-body exposure were also monitored for hand exposures. (Most of the individuals in the Division of Nuclear Medicine wear finger badges.) Typically, a couple of individuals each year receive exposures to the hand as high as approximately 3 rem.

Exposures to the eye lens are not routinely monitored. However, occasional checking with TLD's has revealed that exposures to the eye are roughly comparable to whole-body exposures measured at the collar. Because most of the angiograms and cardiac catheterizations are performed by teaching fellows and residents on a part-time basis, exposures measured at the collar level are low. If these procedures were performed on a full-time basis, annual doses at the collar level as high as 1.2 - 1.8 rem would be anticipated. Notwithstanding the lack of impact of this proposed guideline, it is felt to be unwarranted because it is not justified by the available cataract data.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

As discussed earlier, there are no tasks undertaken at this facility for which annual whole-body exposures are anticipated to exceed 1.5 rem. If angiograms or cardiac catheterizations were performed on a full-time basis, eye lens exposures would be in this range. However, as discussed in the previous paragraphs, residents and teaching fellows perform these procedures on a part-time basis. Thus there would be no cost impact at this facility from the promulgation of this proposed guideline as a regulation. Nevertheless, it is felt that this guideline is thoroughly unrealistic. The net result of this guideline at a typical medical facility would be another individual potentially exposed. Moreover, the opinion was expressed that the continual presence of this individual could possibly make workers feel "edgy," resulting in more time spent on procedures (implying higher exposures) and potentially more accidents. It was felt that this guideline does not make sense from a radiation protection point of view. After some discussion, it was generally agreed that most facilities, rather than complying with the provision of this guideline, would do whatever is required to reduce anticipated exposures below 1.5 rem (thus possibly accomplishing the desired goal).

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

As seen by the data given in the attached Table, some departments (notably diagnostic radiology and cardiology) expose personnel in this range. Although a small percentage of the total number of personnel, exposures may nevertheless be "anticipated" in this range. Personnel monitoring is routinely performed at this facility. Moreover, supervision is provided by members of the Radiation Safety Office to assure that exposures are justified and ALARA. Although there are no certified health physicists on the RSO staff (medical physicists are members of the Radiotherapy Division), it is felt that all or several of the 5 - 6 professionals in the office have backgrounds and experience equivalent to certified health physicists. Also, the opinion was expressed that this guideline is a "reasonable" requirement.

6. Impact of Training Requirements

The existing training program, which was discussed earlier, generally satisfies the proposed guidelines. The basic course includes an hour of physics, an hour of biological effects, an hour on surveys and dosimetry, and a half-hour each of regulations and dose reduction techniques.

7. Impact of the Guidance for the Protection of the Unborn

This facility is currently operating under, and has been for over a decade, the original Alternative d (keep dose to both males and females less than 0.5 rem in any six-month period). Moreover, if a fertile female announces that she is pregnant or desires to become pregnant, she is removed from assignments in brachytherapy, and additional monitoring is performed in an attempt to keep her exposure as close to zero as possible. This policy has the whole-hearted support of the faculty.

8. Impact of Internal Exposure and Combined External Exposure Guidance

This facility conducts an extensive assay program for internal exposures on nuclear medicine technologists. Once a year, whole-body counts are taken. These counts have revealed internal exposures, but they have generally dissipated within 24 hours, implying clearance from the gastro-intestinal tract. Thyroid scans are routinely made on everyone working with radioiodine (mostly those involved in research). This facility is operating under the 15 rem/yr. thyroid limit recommended by the NCRP. Using external counts, thyroid burdens corresponding to 1% of this limit can be readily detected. Finally, urinalyses are routinely performed for all personnel who work with greater than 100 mCi of H-3, and when appropriate for those working with P-32 and S-35, particularly when they are handled in a volatile form.

Ease of compliance with the proposed weighted guidelines (either the EPA weighting scheme or that recommended by the ICRP) would depend on their interpretation by the regulators. If the regulators were to require detailed records of internal exposures, there could be considerable difficulty in compliance. At present, reporting is only required if MPC's are exceeded. But at least a half of internal exposures result from contamination of the hands. If an assay reveals measurable internal deposition, the fraction of the permissible body burden is determined presently. The organ dose is generally not calculated.

Possibly a half dozen times a year a non-negligible body burden is detected at this facility. To calculate internal organ dose, possibly two person-days of effort might be required. To get "really good numbers" might require even more effort.

The question is how this provision would be enforced by the regulators. If it were to be enforced to the same degree that the existing internal exposure guidance is enforced, there would be no significant costs at this facility, or for that matter, at hospitals in general. After all, internal dosimetry is rarely done at most facilities.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

In 1968, the commitment was made at this facility to operate under an internally-mandated W.B. RPG of 0.5 rem. The Radiation Safety Office was expanded (originally with a budget of approximately $200,000 per year; the current budget, at roughly the same level of manpower is roughly $450,000 per year*). It took approximately two years to reach the goal, and a continual effort to maintain it. Moreover, the reductions in maximum individual exposures were not accomplished at a sacrifice in collective dose. In fact, the collective dose over the past 12 years has been reduced from approximately 100 person-rem to approximately 10 person-rem.

These achievements have been attained using few gimmicks and little in the way of capital expenditures. The method can be best described as a constant ratchet. A lot of time was spent by RSO staff monitoring individual tasks. The dose-intensive components of each task were identified. Procedures were revised for these components, resulting in lower doses. Once these new procedures were in place, the RSO would make sure that they were continually followed. These procedures could be as simple as keeping nuclear medicine personnel out of the room during imaging. Personnel were constantly drilled on the fact that once the patient is injected, the patient is henceforth a source.

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*Note that the RSO also has responsibilities outside of this medical facility (consuming an estimated 25% of the resources). See the earlier discussion.

Technology also played a role. The use of syringe shields substantially reduced occupational exposures in Nuclear Medicine. Also, as discussed earlier, digital dosimeters in brachytherapy sensitize personnel to accumulated exposures in real time.

Management procedures in the RSO also played an important role. Each professional is assigned dose reduction goals for a specific division under his or her cognizance. Annual reviews are based in part on the progress made in achieving these goals. In the opinion of one of the professionals, personal pride plays as much of a role in motivating the staff as the potential for financial reward.

Concern was expressed about the nuisance of the reporting requirement should the lower RPG be exceeded (which has occurred once over the past two years).

A.4 SMALL HOSPITAL

This 230-bed hospital is located in a suburb of a relatively large metropolitan area. Operating at 80 - 85 percent of capacity at the time of the case study, the facility employs approximately 650 personnel. There are two departments in which radiation sources are are used — Radiology and Nuclear Medicine.

The Department of Radiology has six fixed diagnostic X-ray machines, one mobile fluoroscopy unit and three portable diagnostic units. Approximately 45,000 procedures are performed annually, high for a facility of this size and for the number of machines available. There is no CAT scanner within the hospital (the radiologists operate one in their offices outside of the hospital). A therapy program is planned for the future. Most of the fluoroscopy is performed during the scheduled portion of the week, which is eight hours, seven days. However, only about one-half of the total number of procedures are performed during the scheduled hours of the week.

The Department is operated by seven radiologists, who also maintain an outside practice. Eight part-time radiologists are also affiliated on a part-time basis with the Department. There are approximately 30 radiologic technologists employed, all of whom are registered by the American Registry of Radiologic Technologists. The hospital is affiliated with a community college which trains radiologic technologists. Other than this program, there is no teaching program or residency within the facility.

The Nuclear Medicine Department is small, with one stationary imaging camera performing approximately 120 scans per month (down roughly 50 percent from the period prior to the installation of a CAT scanner in the outside offices of the affiliated radiologists.) An outside nuclear pharmacy is used to prepare unit dosages, which consist primarily of Tc-99m, plus small amounts of thallium, gallium, xenon, and I-131. The hospital no longer has its own molybdenum generator for the preparation of Tc-99m dosages. A limited amount of thyroid radiotherapy is also performed with I-131 (possibly 2 - 3 times per year). Nearly all procedures are performed during an eight hour, five-day week.

The Department is operated by two full-time pathologists (with no outside practice), with the assistance of 2 - 3 technologists (two of them registered technologists in nuclear medicine). Additionally, 6 - 7 laboratory technologists who perform RIA's and are officially in a different department are under the radiation protection cognizance of the Nuclear Medicine Department.

Radiation protection is the separate responsibility of each Department, each of which maintains its own Radiation Safety Officer (physicians). The Manager of the Radiology Department (B.S. in Radiology Administration and A.A. in Radiologic Technology; four years of experience at this hospital) maintains cognizance over personnel outside of these departments, such as nursing services. He also conducts surveys and coordinates personnel monitoring for all departments outside of nuclear medicine. He is assisted in these radiation protection activities by the Chief Technologist in the Department of Radiology.

Once a year, a certified health physicist is called in to check the X-ray tubes for leakage. He may also be consulted from time to time on questions relating to shielding. For example, he was retained to specify the shielding requirements for a new special procedures' room.

The Chief Technologist in the Nuclear Medicine Department assists the Radiation Safety Officer (Nuclear Medicine) in coordinating radiation safety. She has an A.A. in Laboratory Technology augmented by 6 - 8 weeks in a local hospital with a nuclear medicine department, and approximately nine years of experience in this hospital.

All employees in the Radiology Department, including Aides (file clerks, transport workers, and darkroom technicians), are monitored for whole-body exposure. Badges are worn above the apron, on the collar, for all technologists except those assigned to angiography. The technologists in angiography and all of the radiologists additionally wear under-the-apron badges. Most (79%) of the annual exposures are less than measurable. The remainder are less than 0.5 rem, with five individuals receiving greater than 0.5 rem, the highest exposure of which was approximately 1.5 rem in the most recent 12-month period (the reading might have been attributable to accidental exposure of the badge). The exposures to the Aides in the Radiology Department are usually less than measurable.

Only the two personnel in Nuclear Medicine who inject patients receive measurable whole-body exposures. Over a recent 12-month period, these exposures ranged from 0.5 to 1.0 rem. The technologists who perform RIA's receive no measurable whole-body exposures.

Approximately 30 nurses assigned to the operating room (because of the potential exposure from mobile fluoroscopy) to the floor on which brachytherapy patients are assigned, and to pacemaker surgery, are monitored. All of these exposures were less than 0.1 rem in a recent 12-month period.

A few badges are also assigned to the cardiologists and anaesthesiologists involved in pacemaker surgery, and to the EKG technologists and cardiologists involved in thallium stress testing. Recent annual exposures to these individuals were less than 0.4 rem. Finally, control badges, which indicated fields less than 0.05 rem per year in a recent 12-month period, are mounted in the intensive care and coronary care rooms.

In total, approximately 70 film badges are assigned to personnel. They are read monthly by an outside dosimetry service at a cost of $1.25/badge/month.

There is no formal training program in radiation protection at the hospital. Only registered technologists are hired, and they are instructed in radiation protection principles in the course of their two-year training programs. At least one of the colleges offering such a degree features a one-semester course in health physics. Student technologists hired by the hospital must pass the registry examination within six months of the date of their employment.

New hires get a two week orientation in their departments. Additionally, quarterly staff meetings are held to go over problem areas. Non-radiologist physicians are only allowed to operate radiation equipment under the supervision of a radiologic technologist. Nurses and Aides get instruction in the use of the lead-lined apron and where to stand during procedures involving sources of ionizing radiation.

One of the reasons given for the lack of a formal instructional program in radiation protection principles is the high turnover rate of nursing staff. If such a program were initiated, the staff is prepared with a slide show put out by the Bureau of Radiological Health (however, this may be oriented toward minimization of dose to patients.)

Radiologic technologists earn between $13,500 and $17,000 per year. These salaries are comparable to, and possibly somewhat on the high side of those of ordinary laboratory technologists.

1. Impact of Reduction in W.B. RPG

There would be no impact at this facility of a change in the W.B. RPG from 3 rem/qtr. to 5 rem/yr. The highest exposure recorded over a recent 12-month period was approximately 1.5 rem, to a technologist involved in angiography. Angiography is the highest exposure procedure because the fluoroscope may be on for relatively long periods of time — possibly as long as one hour. However, even this measured dose was not indicative of the real whole-body exposure, since it was measured at collar level and may have been an accidental exposure to the badge. The under-the-apron exposure for the same individual was .020 rem.

The opinion was expressed that higher exposures are likely to be seen at teaching hospitals, since residents are not familiar with radiation protection principles. For similar reasons, high exposures are likely to be recorded for cardiac catheterization.

2. Impact of Reduction in Accumulated Exposure Limit

There would be no impact at this hospital from a reduction in the accumulated exposure limit from 5(N-18) to 100 rem. The highest accumulated exposure is 4.3 rem to a physician.

This is a realistic objective for any hospital. A problem could conceivably be encountered in cardiac catheterization. However, given proper shielding and instruction, there is no reason why this limit could not be met at any hospital.

This hospital encounters little difficulty in obtaining records from previous employers.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Finger badges are worn in nuclear medicine and RIA. Measured levels in RIA are negligible. The maximum in nuclear medicine over a recent 12-month period was approximately 2.5 rem. Hand doses were considerably higher when unit dosages were prepared in-house. However, the highest annual dose measured by a ring badge at that time was 4.0 rem, considerably below the proposed 50 rem guideline.

There is some suspicion that some of the radiologists may be pushing up against the limits, since the largest exposure during fluoroscopy is to the hands of the radiologist. However, hand exposures are not monitored since it is allegedly difficult to wear ring badges under the sterile gloves.

Eye monitoring has never been carried out. However, there is no reason to believe that the lens of the eye receives any higher exposures than the monitor worn on the collar. As discussed earlier, the highest measured exposure to the collar monitor over a recent 12-month period was 1.5 rem. Therefore, the proposed limit of 5 rem to the eye lens would have no impact at this hospital.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Unless above-the-apron monitors are considered indicative of whole-body exposures, exposures to personnel are not "anticipated" in this range. If they were, the only procedure in which annual exposures would be anticipated to exceed 1.5 rem is angiography. Over a recent 12-month period, one individual involved in angiography received approximately 1.5 rem, measured at the collar level.

Roughly 2 - 3 angiograms are performed daily in one special procedures' room. The average procedure takes two hours, only approximately 15 - 20 minutes of which is actual fluoroscopy time. Therefore, it may be conservatively estimated that monitoring would be required under the proposed guideline for a period of 1 - 2 hours per day.

There are presently no personnel in the hospital with backgrounds and experience levels equivalent to those of health physicists or medical physicists. The closest is the Manager of Radiology, who has a B.S. in Radiology Administration. Therefore, to comply with the monitoring and supervision requirements of these guidelines, a full-time health physicist or medical physicist would have to be hired (subject to the resolution of the question regarding the whole-body exposure monitor location).

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

At least two individuals in Nuclear Medicine and five in Radiology received exposures over a recent 12-month period in excess of 0.5 rem. Therefore, it may be "anticipated" that personnel in these two departments would receive annual exposures in excess of 0.1 RPG.

The monitoring requirements of the proposed guidelines are currently being carried out. To a lessor extent, so are the supervision requirements. However, there are no personnel currently employed by the hospital with backgrounds and experience equivalent to those of health physicists or medical physicists. Therefore, a consultant would be retained to satisfy this requirement. As discussed earlier, a certified health physicist is used once a year to check the X-ray tubes. It is envisioned that this individual would be consulted to ensure that exposures are justified and ALARA. it is estimated that this could be done on an annual basis in 2 - 3 days, at a consulting cost of $500 - $1000.

6. Impact of Training Requirements

It is felt that at least in the case of the technologists, instruction in radiation protection principles is the responsibility of the schools. Ten years ago, the typical curriculum in radiologic technology did not include instruction in levels of risk. Currently, a course in health physics, which does include quantification of risk, is offered.

If nurses were instructed in radiation protection principles, all 300 nurses would have to be included, because of rotation. A 1 - 2 hour course is envisioned, in which a video tape would be shown, followed by questions from the floor. The opinion was expressed that this would be a good thing because of the large number of questions asked routinely by nurses about radiation and attendant risks.

7. Impact of the Guidance for Protection of the Unborn

Approximately 75% of the technologists and 90% of the nurses are females; nearly all of the females are of child-bearing age.

At present, if a female in the Radiology Department announces that she is pregnant (three are currently pregnant), she is excused from any fluoroscopic procedures. This limits her dose to less than 0.5 rem for the remainder of her pregnancy. Although the situation has not been encountered in Nuclear Medicine, the dose to a pregnant technologist could be limited to less than 0.5 rem over a nine-month period by limiting her activities (i.e., no more injection of patients, even though shielded syringes are used). This could easily be accomplished.

If a technologist announced her intention to become pregnant, she could be pulled out of fluoroscopy for a month or two (the only procedure for which above-the-apron exposures in excess of 0.2 rem/mo. are possible). Over a recent 12-month period, two individuals in the Department of Radiology received above-the-apron exposures in excess of 0.2 rem in a one-month period. However, it would be impractical to keep technologists out of fluoroscopy for extended periods of time, as most certainly would be required under Alternative b. Eventually, they would have to take a leave of absence. Implementation of Alternative b would be no problem in nuclear medicine, since there are no jobs in which exposures could exceed 0.2 rem/month.

If under-the-apron measurements were acceptable estimates of whole-body exposures, there would be no problem in implementating Alternative c, since no one in the Department of Radiology might be expected to receive an under-the-apron exposure in excess of 0.2 rem. If not, this hospital would have considerable difficulty in complying with this guideline.

Remote control fluoroscopy rooms could be installed at an approximate cost of $450,000 (an existing room could not be adapted). This hospital has three fluoroscopy rooms. However, angiography would be eliminated because it is impossible to perform this procedure remotely.

Approximately five technologists (female) work the angiography room. These could be replaced by five male radiologic technologists, if they could be recruited. There are probably not enough male technologists in this area to satisfy the demand.

The opinion was expressed (by a female) that Alternative c is not equitable. It is not fair to hire males exclusively to perform fluoroscopy. Female technologists are aware of the risks from the start, and if they were not willing to accept the risks, they would get out of the field.

8. Impact of Internal Exposure and Combined External Exposure Guidance

The only potential for internal exposures in this hospital is in the therapeutic injection of I-131 (approximately 200 mCi). Approximately 24 hours after this procedure, a thyroid uptake scan is performed. However, there have never been measurable uptakes (in approximately nine years). Moreover, there used to be a lot more I-131 used in nuclear medicine. Most of this has been supplanted by Tc-99m.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

If under-the-apron measurements were acceptable estimates of whole-body exposures, this hospital is currently complying with this reduced RPG. If not, the only procedure for which there might be a problem is angiography. At present, approximately five technologists and five radiologists work this procedure. A 1.5 rem RPG could be achieved with rotation of personnel. However, the collective dose would increase.

B.1 PRIVATE PRACTICE IN RADIOLOGY

This medium-to-large private medical practice, encompassing two private offices and a medium-sized, parochial hospital (approximately 450 beds), is located in a suburban area. The practice includes nine physicians, all radiologists (most of whom are additionally certified by the American Board of Nuclear Medicine).

The two private offices are located within a mile of the hospital and are open eight hours a day, five days a week. The offices contain four radiography and fluoroscopy units and three straight radiography units (two of which are used for mammograms), all of which are single phase. Soon, a CAT scanner will be added to the list of equipment. Approximately 60 patients are seen daily. The support staff in these offices is comprised of seven technologists, four typists/receptionists, and one darkroom technician. The larger of the two offices is always staffed by a physician; a physician is usually physically located at the smaller office, or is available on short notice.

The physicians in this private radiology practice also run two of the departments in the hospital — radiology and nuclear medicine. This includes the monitoring of personnel and the responsibility for radiation safety. One of the physicians is the Radiation Safety Officer for the hospital. His responsibilities extend to the use of radiation sources in the operating room and the emergency room. (The hospital does not perform radiation therapy — except an occasional thyroid implant — or heart catheterizations.)

The radiology department in the hospital encompasses 13 X-ray units and one CAT scanner. Angiography is performed in the hospital, but not in the private offices. The department employs approximately 60 full-time equivalents.

The nuclear medicine department performs approximately 475 scans monthly. Almost all of the scans are made using Tc-99m. Some gallium is used for scans of the abdomen and chest; radioiodine is frequently used for thyroid uptake, and xenon for lung scans. An occasional thyroid therapy is also performed by the nuclear medicine department.

Most of radiopharmaceuticals are now purchased from an outside supplier as single unit dosages. This results in lower exposures to the technologists. Radioiodine dosages are still prepared within the hospital. The nuclear medicine department employs approximately 10 full-time equivalents.

It is estimated that approximately 150 patients are seen daily in the hospital. Most of these patients are seen during regular hours — 7:30 a.m. to 10:30 p.m., five days per week, plus a half day on Saturday.

It is policy to monitor all physicians and technologists, but not clerical personnel or nurses. Badges are now worn outside the apron at the collar level, as required by the state, although at one time it was standard procedure to wear badges under the apron. It is felt that collar level badging is good radiation protection practice, as long as the readings are within limits. If not, two badges should be worn, one inside and the other outside the apron, using the inside badge as a measure of whole-body exposure. As a matter of fact, double badging is done at this facility for angiography procedures.

It is also standard practice at the hospital to wear ring badges in the nuclear medicine department. Ring badges are seldom worn in radiology, although a physician performing arthrograms receives average hand exposures of approximately 0.13 rem/month. The hand is never placed in the primary beam.

During the year 1980, approximately 80 personnel, including those in the private offices were badged. Of these, 80% received measurable whole-body exposures. The average exposures were 0.05 rem to the physicians and 0.1 rem to the technologists. The maximum exposure was approximately 0.9 rem, to a nuclear medicine technologist. No personnel received exposures in excess of 1.0 rem.

The technologists are typically female, ranging in age from 20 to 30 years. The salary range is $10,000 to $15,000 annually.

Although the hospital is not a teaching facility, some of the interns and residents are drawn from a medical school in the metropolitan area. None of these, however, are currently in radiology, although some instruction is provided to them about procedures in radiology.

1. Impact of Reduction in W.B. RPG

The reduction in the allowable annual whole-body exposure from 12 rem to 5 rem would have no impact. The highest annual exposure in 1980 was roughly 0.9 rem, greater than a factor of five below the proposed limit.

The opinion was expressed that the main problem in radiation safety is the use of radiation sources by physicians not properly trained in their utilization. These are usually internists, orthopedists, or cardiologists with small practices who have little or no appreciation for radiation safety. They do not generally employ trained technologists, and even the quality of the X-rays is poor.

2. Impact of Reduction in Accumulated Exposure Limit

The reduction of the accumulated exposure limit from 5(N-18) rem to 100 rem would have no impact. In fact, the opinion was expressed that the accumulated exposure limit could well be even lower.

In this practice, the highest accumulated lifetime whole-body dose for a physician is 3.7 rem and for a technologist, 11 rem (in nuclear medicine for 15 years). The physician who founded the practice 15 years ago has accumulated 0.8 rem. (Some of the time that these whole-body exposure were accumulated, the film badges were worn under the apron.) This experience suggests that the cumulative exposure limit could be set at 25 rem, although this might be cutting it a trifle thin.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Neither the proposed limit on the hands nor that on the eye would pose a problem. Only the individuals in nuclear medicine routinely wear ring badges. For these, the maximum cumulative hand exposure is 43 rem, obtained over a period of 15 years. Thus the proposed limit is a factor of 15 higher than the high average annual hand exposure. Although it is possible to get a significant dose to the hands in radiography, the radiologists are trained to avoid direct exposure to the beam unless lead gloves are being worn.

Dose to the eye has never been directly measured. Assuming that the collar-level reading is an appropriate surrogate for the eye, the maximum cumulative lens dose is 6.1 rem over ten years, or only approximately 0.6 rem/year, on the average. This exposure was accumulated by an individual who performs angiograms. Thus, the proposed 5 rem limit to the eye would not pose a problem for this practice.

If the eye limit were to pose a problem, it could be easily rectified by providing lead glasses to the staff. The cost would be minimal and there would be little resistance to wearing them.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Noone employed by the practice is anticipated to receive an annual whole-body exposure in excess of 1.5 rem, since there were no whole-body exposures in excess of 1.0 rem in 1980. Therefore, a full-time "radiation protection professional" would not be required for this practice.

If a supervisor were to monitor procedures involving significant exposures, it is not clear what would be learned through such monitoring. The dose rate for each procedure is relatively constant. Therefore, the exposure received is a function of the time spent on each procedure. This varies, depending on a number of random factors. "If you're putting in a pacemaker and it takes too long, what do you do, stop?" To summarize, the opinion was expressed that monitoring during procedures performed by this practice would accomplish little in reducing occupational radiation exposures.

Another issue relates to the definition of a "radiation protection professional". The Radiation Safety Officer is a Board-certified radiologist. He studied the physics of radiation and is interested in radiation safety. However, he is not trained in radiation protection. Therefore, strictly speaking, his background and experience is not equivalent to that of a "radiation protection professional." Thus, if "radiation protection professionals" were required to monitor the procedures of this practice, they would have to start from scratch in employing them. The opinion was expressed that there aren't enough medical physicists to satisfy the requirements in just this one metropolitan area.

5. Impact of the Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

At present, the practice is monitoring all individuals expected to receive exposures in excess of 0.5 rem/year. In fact, 20% of those monitored received no measurable exposure at all in 1980.

The supervision provision of the guidance, however, may pose a problem. Presently, a part-time physicist is used as a consultant to checkout and calibrate the X-ray units. He comes in twice a year, but would hardly be defined as "available" for purposes of ALARA monitoring. Thus, the responsibility for assuring that exposures are justified and ALARA falls on the shoulders of the Radiation Protection Officer. He keeps up with NRC guidelines, coordinates with the State, and reviews the radiology literature relating to radiation protection. On the average, he spends somewhat less than 10% of his time on radiation safety matters. However, as discussed earlier, he does not consider himself a "radiation protection professional" or its equivalent. The hospital has a research committee that reviews new procedures, but it is not interested in radiation. Therefore, the supervisory function called out in this guideline is not currently being provided.

6. Impact of Training Requirements

There is no formal training in radiation protection provided to the employees of the practice, either those in the office or those in the hospital. Weekly conferences are held in the hospital, but these are rarely concerned with radiation. The technologists do occasionally attend formal hospital lectures devoted to radiation protection principles. There are no corresponding lectures for physicians, nurses, or clerical personnel potentially exposed.

The technologists get training in radiation protection principles during their formal education. This consists of a two-year program at a junior college. This program includes quantitative guidance in levels of risk.

7. Impact of the Guidance for Protection of the Unborn

The practice is presently operating within the framework of Alternative a. All female workers are instructed to inform their supervisors as soon as they know that they are pregnant. If they are in radiology, they are not allowed to do fluoroscopy or portable X-ray procedures. If they are in nuclear medicine, they are placed elsewhere, or if there are no available slots, they are asked to take a leave of absence. At present, there are no known pregnant technologists.

If Alternative b were promulgated, the only workable mechanism would be to ask women, at the time of hire, if they would avoid jobs with the potential for exposures in excess of 0.2 rem/month. (The only procedures for which the potential exists for exposures in excess of 0.2 rem/month are in nuclear medicine, and possibly angiography. In 1980, noone received an exposure in excess of 0.2 rem in any one month.) If the answer were affirmative, they wouldn't be hired. If they were hired, and then requested transfer to other activities not involving potential exposures in excess of 0.2 rem, they would have to be discharged. It would be too difficult to find other jobs for them within the hospital.

Alternative c is totally unrealistic and would be unworkable. The biggest problem would be with the women themselves, who would proclaim that their liberties were being abridged.

8. Impact of Internal Exposure and Combined External Exposure Guidelines

The only place where internal exposures could be received is in nuclear medicine. At present, there is no monitoring for internal exposures. However, there are not expected to be any internal exposures. All Tc-99m dosages are injected. All iodine dosages are swallowed. The only airborne contamination is from Xe-133, and this is exhaled into a balloon and allowed to decay. It would be difficult to implement an airborne contamination control program using MPC's, because the physicians are not accustomed to working with exponential notation.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/year

Because of the relatively low W.B. exposures in this practice, it would be feasible to reduce the RPG to 1.5 rem/year without a cost impact. However, it is felt that it would be a mistake to impose this limit at this time. It is cutting it too close for comfort. It would not allow enough breathing room.

B.2 PRIVATE PRACTICE IN NUCLEAR MEDICINE

This is a small private practice in nuclear medicine, which is conducted within the framework of a large, multi-office pathology practice covering a reasonably large metropolitan area. Nearly all of the nuclear medicine work is conducted in the main laboratory, with only an occasional capsule administered in one of the seven branches. There is an affiliation with the nuclear medicine departments at three moderate-sized hospitals (one in an adjacent state), but the radiation protection programs at these facilities are administered by the hospitals (one of which is the subject of a separate Case Study).

This practice is not typical of the private practice of nuclear medicine in this country. Only approximately 25% of nuclear medicine is administered by pathologists; most of it is administered by radiologists (at least 50%); the remainder by a number of specialties. The trend is toward control of nuclear medicine by the radiologists.

The majority of pathologists (at least 50%) are salaried and work exclusively for hospitals. Another 30% run hospital pathology laboratories, but do their own billing. The remainder take a percentage of the pathology lab receipts from the hospital.

There are approximately 25 groups like this practice throughout the country, each consisting of approximately ten pathologists. It is estimated that there are roughly 10,000 pathologists in the country.

The main laboratory of this practice services approximately 300 patients daily. Out of this patient load, approximately 100 radio-immuno-assay (RIA) procedures are performed daily. (Several RIA procedures may be performed for a single patient.) The number of scans, however, averages only approximately ten per week. Additionally, approximately 20 patients per year are treated for thyroid cancer on an outpatient basis.

Most of the RIA's use small amounts of I-125 or I-131 (generally less than 10μCi). Most of the actual work is performed in well counters. The exposure to personnel is negligible.

The out-of-hospital procedures are limited to intakes of 30 mCi (according to the limits set by the NRC). For this reason, exposures to office personnel are low. Because of the intake limitations, the trend is toward hospital practice of nuclear medicine, exclusively.

Four individuals at the main laboratory come into contact with radioisotopes. These are three technologists and one of the pathologists. (Only one of the nine pathologists in the practice is involved in the practice of nuclear medicine.) Two of the three technologists generally confine their activities to RIA.

Approximately four years ago, the decision was made to buy unit dosages from an outside nuclear pharmacist. Prior to that time, a molybdenum generator was used to produce Tc-99m, and exposures were somewhat higher (although primarily to the hands).

It is the policy to provide individual monitors to only those individuals who work with radioisotopes. The other 47 employees at the main laboratory are not monitored. Moreover, with one exception, the one or two individuals (generally a receptionist and a technologist) at each of the seven branches are unmonitored. The exception is a branch that conducts routine chest X-rays as part of a contract to provide pathology services to a government agency. Personnel at the branches seldom come into contact with radioisotopes; when they do, it is only to administer a capsule ($< 50\,\mu$Ci) for which a scan is conducted at a later date at the main laboratory.

When radioisotopes were generated at the main laboratory several years ago, hand exposures were routinely monitored using ring badges. At that time, it was not unusual for the ring badges to register dosages in excess of 2.5 rem/year. Now that unit dosages are purchased from an outside vendor, extremity exposures are believed to be comparable to whole-body doses. Therefore, only whole-body doses are monitored.

An exposure record for the technologists at the main laboratory is provided in the attached Table. The cumulative lifetime exposure to the pathologist involved in the practice of nuclear medicine is roughly 0.4 rem. (The exposures for the year 1980 are not available.) The changeover from the use of internally-generated unit dosages to the purchase of unit dosages from an outside vendor occurred in 1978.

The exposures displayed in the Table are not typical for the practice of nuclear medicine. For example, two of the four technologists employed by one of the hospitals

List of Technologists with Highest Accumulation of Whole Body Radiation for 1970-1979

	ANNUAL EXPOSURE IN REM										Cumulative
	1970	71	72	73	74	75	76	77	78	79	Total Whole Body 1970-79
#1	0.30	0.33	1.10	0.24	0.61	0.31	0.484	0.428	0.422	0.226	6.210
#2	0.77	1.17	0.45		0.28	0.374	0.397	0.436	0.329		6.574
#3			0.28	0.44	0.10	0.077	0.103	0.082			1.331
#4				0.43							
#5					0.49	0.09	0.053	0.096	0.012		0.741
#6					0.15	0.120	0.159	0.291	0.39	0.024	0.782

affiliated with this group of pathologists receive on the order of 0.2 rem whole-body exposure monthly. However, approximately 50 scans are performed weekly in this hospital, compared with the ten scans per week for the private practice.

Nuclear medicine technologists receive lectures in radiation protection during their regular training program. They learn about radiation levels, the maintenance of records, the disposition of radioisotopes, etc. They do not receive formal lectures on the quantitative levels of risk from radiation.

A formal course in medical technology is also given by this pathology practice. Most of the trainees have three to four years of college prior to taking the course. The course, which is one year in duration, is recognized by the American Society of Clinical Pathology. A normal part of the course is training in RIA. If a specialty in nuclear medicine technology is desired, experience in imaging is obtained at an affiliated hospital.

Nuclear medicine technologists earn from $15,000 to $25,000 annually. The salary for a chief technologist could go as high as $30,000/year.

1. Impact of Reduction in W.B. RPG

The reduction in the allowable whole-body exposure from 3 rem per quarter to 5 rem per year is expected to have no immediate impact in this practice. As a matter of fact, reference to the attached Table indicates that annual exposures are running at least one order of magnitude lower.

However, concern was expressed about the need for flexibility in the future. Should some breakthrough occur, resulting in the need for higher exposures, it would be detrimental to have lost the degree of flexibility provided by the existing limits.

Also, concern was expressed about the imposition of the lower limit on some radiology departments. As a matter of fact, even the practice of nuclear medicine in hospitals may well be pushing up against this proposed W.B. limit. As discussed earlier, technologists at a hospital affiliated with this private practice are receiving exposures as high as 0.2 rem/month.

2. Impact of Reduction in Accumulated Exposure Limit

The limit would have no impact on this private practice of nuclear medicine. Currently, the highest accumulated exposure for a technologist is more than one order of magnitude below this limit. The accumulated exposure of the pathologist is in excess of two orders of magnitude lower.

Although some concern was expressed about the remote possibility that this limit could restrict future experimental work, less concern was expressed about the proposed lifetime dose limit than the proposed annual limit. That is because there is intrinsic flexibility in a cumulative exposure limit that is not available in an annual limit. If an exposure is relatively high one year, the individual can be removed from work involving high fields of radiation in subsequent years to limit the cumulative exposure.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

There is no reason to believe that exposures to the lens of the eye are any higher than measured whole-body doses. However, exposures to the hands, when unit dosages were prepared in-house, routinely exceeded 2 rem/year, and occasionally ran as high as 0.5 rem/month. Now that outside vendors are being used, hand exposures are comparable to whole-body exposures. However, exposures to the hand were and are well below the proposed limits (previously, by roughly one order of magnitude, and now by more than two orders of magnitude).

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

It is not "anticipated" that anyone would receive an annual exposure in excess of 1.5 rem in this private practice of nuclear medicine. Therefore, the impact of this proposed guideline is negligible.

The reason, however, for the relatively low exposures in this practice is probably the small number of scans. In an affiliated hospital, where the frequency of scans is a factor of five higher, annual doses are anticipated to be greater than 1.5 rem per year. Therefore, a supervisor would be required to be present before and during each task "significantly contributing" to the annual exposure. (It was suggested that holding the patient's head during a brain scan is the largest single contributor to occupational exposure in the practice of nuclear medicine.)

The question arose regarding the equivalency of the background and experience of a nuclear physician to a "radiation protection professional." The physician is present during each scan (he could presumably carry out the monitoring requirements in the guidelines in addition to his other duties). The pathologist who practices nuclear medicine in this practice is also the Radiation Safety Officer. He took courses in physics in college and, of course, took the required six-months' course in nuclear medicine required for the NRC license. This course includes training in nuclear physics. He feels that this background should qualify him to satisfy the "radiation protection professional" requirements of this guideline. He feels that the M.D. degree plus the NRC license are sufficient to satisfy this requirement. Moreover, he feels that most radiologists are also equivalent in background and experience to medical physicists. (This particular physician has additionally trained more than 700 physicians over a period of 20 years for the NRC license. This two-week course is sponsored by the American Society of Clinical Pathologists.)

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

Although whole-body exposures in this practice have not exceeded 0.5 rem in several years, they have come close enough to this limit so that it is reasonable to "anticipate" annual exposures in this range. The individual exposure monitoring requirement of this guideline has been satisfied for years. The availability of a "radiation protection professional" in satisfaction of this guideline hinges on the arguments presented above regarding the qualifications of the nuclear physician. If the licensed nuclear physician is indeed equivalent to a medical physicist, as argued in the previous section, then this private practice would not incur costs resulting from the imposition of guideline. If not, then an outside consultant would have to be retained and be "on-call", to assure the "availability" of a "radiation protection professional".

6. Impact of Training Requirements

As discussed earlier, the prescribed training course for a nuclear medicine technologist includes instruction in radiation protection principles. This includes instruction on the immediate effects of relatively high levels of exposure. No guidance is given, however, on the long-term stochastic effects, either qualitative or quantitative. Moreover, it is felt that it would neither be prudent nor productive to include these effects in a routine training course because of the high degrees of uncertainty involved.

7. Impact of Guidance for the Protection of the Unborn

At present, women who are known to be pregnant are not allowed to work in nuclear medicine. If a woman working in this practice were to declare herself pregnant, she would be directed to other tasks not involving the potential exposure to radiation. Thus, this practice is operating within the constraints of a mandatory version of Alternative a.

Alternative b is felt to be too restrictive. Most of the medical technologists are female and most are in the child-bearing years. Although an exposure of 0.2 rem in one month would be atypical for this practice, it is not unfeasible, and is a regular occurrence in the nuclear medicine department of an affiliated hospital. Therefore, Alternative b would prevent these women from being hired in the first place.

Alternative c is felt to be a "disaster". Because of the atypical low exposure levels in this practice, women are not expected to receive exposures in excess of 0.2 rem/month. However, in the more typical hospital environment, such exposure levels are routinely received. Therefore, all women of child-bearing age (the great majority of the technologists) would have to be removed from their jobs in nuclear medicine. The costs would be very high, since there are openings for approximately 25,000 medical technologists at present, and only 12,000 trained technologists are available for these jobs. At present, there are not enough training programs in existence to turn out medical technologists in sufficient numbers to satisfy the demand.

8. Impact of Internal Exposure and Combined External Exposure Guidance

Several years ago, when unit dosages were made up in-house, there was concern about potential internal thyroid exposures. Therefore, thyroid uptake monitoring was performed, but no significant uptakes were measured. At present, there appears to be little potential for internal exposures.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/year

As discussed in previous sections, W.B. exposures in excess of 1.5 rem/year are not anticipated in this practice. Therefore, although the decrease in flexibility engendered by this postulated reduction in the RPG was decried, no significant costs would accrue to this private practice.

The costs at the affiliated hospital, however, would be significant. At least two technologists receive annual exposures in excess of this level. At least one additional worker, and most probably two, would have to be recruited and hired. The serious shortage of medical technologists was discussed in the previous section. If it were possible to hire additional workers, the collective dose would be expected to increase.

C.1 LARGE CONTRACT INDUSTRIAL RADIOGRAPHER

This large engineering services firm performs soils testing, materials testing, and non-destructive testing (NDT) of metals. NDT uses visual, ultrasonic, eddy current, magnetic particle, dye penetrant, and radiographic techniques. For total volume testing, radiography and ultrasonics (which has become more widely used since the acceptance by the American Welding Society in 1969) are used approximately equally. Overall, roughly 25% of NDT is performed by radiography.

With a total employment of approximately 1,100, the company has 16 offices. Radiography is performed in nine of the 16 offices. Licenses are required, therefore, by several agreement states as well as by the NRC. The firm employes approximately 100 licensed radiographers.

Roughly one-half of all radiography in the U.S. is performed by outside contractors, such as this firm. There are a handful of such large national firms, while each state has a couple of 10 - 20 person companies that operate regionally. There are also a number of "mom and pop" firms that do not operate under the two-man team, unwritten rule.

Technicians employed strictly as radiographers, as opposed to technicians who work for testing firms, generally receive higher annual exposures. This is because these technicians perform radiography full time, whereas the testing laboratory technicians may perform a large variety of tasks (i.e., ultrasonics, visual inspections, etc.).

Radiography is performed in the following four modes in this firm:

1. In the laboratory at the firm's facilities. Clients are urged to bring pieces to the firm's facilities to reduce costs. In this mode, a radiographer may work alone (others are available, should assistance be needed).

2. On-site radiography at distances up to 30 miles. A minimum of a two-man team, one of whom must be a licensed radiographer, is always sent. For these relatively close jobs, film processing may be performed at the home facility, where an automatic film processor is used.

3. On-site radiography at distances beyond 30 miles. At these distances, a mobile darkroom and possibly an extra technician are generally sent with the team.

4. Radiography with the client's equipment. Only the people are sent. The client's sources and darkroom facilities are used.

The firm is licensed to possess 100 Ci sources of Co-60 and Ir-192, and purchases sources at the 100 Ci level. They are currently in possession of 30 Ir-192 sources and four Co-60 sources (used for thick/heavy sections). Approximately 10% of the radiography is performed with approximately 10 X-ray machines. Depleted uranium collimators are used in conjunction with the radioisotope sources. In addition to providing a well-defined beam, the collimators provide at least a factor of 10 attenuation.

In conjunction with the firm's soil testing activities, Troxler moisture/density gauges are also used. These are generally Cf-252 or Am-Be (up to 50 mCi) neutron sources. The individuals who use these sources are generally not radiographers.

The firm has designated eight individuals as Radiation Safety Officers (RSO's). Each RSO is responsible for a region, which may be only a single state. The backgrounds of the RSO's range from senior technicians to professional engineers, and they have generally been involved in radiography. Each RSO attends a course of at least 40 hours conducted by Louisiana State University or Gamma Industries (a supplier of sources). The firm has also designated a Radiation Protection Coordinator, who reports to the Director of Engineering, who in turn reports to the President. There are no health physicists employed by the firm.

All radiographers and radiographer's assistants are monitored. Dosimetry is performed with TLD's which are read monthly, at a cost of $2.30/mo./badge. Pocket ion chambers are also worn. Readings from these instruments are taken daily and records turned in weekly. Roughly 75 personnel are monitored regularly. Approximately 75 additional individuals are monitored some of the time. Measured whole-body exposure distributions for the past three years are given in the attached Table. The large number of monitored employees in the year 1980 is anomalous, and was due to an extraordinarily large project undertaken during that year.

Whole-Body Exposure Distributions

	Year		
	1980	1979	1978
Less than meas.	38	37	16
< 0.1 rem	144	30	38
0.1 - 0.25 rem	50	27	23
0.25 - 0.50 rem	17	13	17
0.50 - 0.75 rem	7	3	2
0.75 - 1.00 rem	0	0	4
1.00 - 2.00 rem	0	4	4
> 2.00 rem	0	0	0

Additionally, the 50 or so employees using Troxler moisture/density gauges are monitored for gamma exposure (although the sources also have a neutron output). The exposures to these sources are less than 0.5 rem/yr.

Total labor costs for the firm last year were $20M. The cost for radiographers was $1.5M. Salaries for radiographers range from $5 to $15/hr. Level III radiographers, who are also supervisors, can earn more than $15/hr. The age range of radiographers is 19 to 45 years.

Radiographers and radiographer's assistants receive a minimum of 16 hours of formal training in the principles of radiation safety and three months of on-the-job training. They must also pass a written examination in accordance with NRC's rules and regulations (10 CFR Part 34, Appendix A). Personnel who use the moisture density gauge receive instruction from the Radiation Safety Officer and some attend a course given by the vendor.

1. Impact of Reduction in W.B. RPG

The change in the allowable whole-body exposure limit from 3 rem/qtr. to 5 rem/yr is expected to have no cost impact on this firm. Over the past several years, the highest whole-body exposure was in the range of 1 - 2 rem.

It is not difficult to keep annual exposures safely below the 5 rem RPG. Action levels are established within the firm of 18 mr/day, 90 mr/week, and 1.25 rem/qtr. If these levels are exceeded, the RSO steps in to find out what's going on.

It is not difficult for a radiographer to limit his exposure to 18 mr per day, even if he shoots as many as 50 - 100 films. It can be done by getting away from the source. The one situation in which this is difficult is in cross-country pipeline radiography. Here it is difficult to get away from the source, and it might be difficult to live within a 5 rem RPG. However, the case study firm no longer does cross-country pipeline radiography on a full-time basis.

The "vagabond radiographer" was mentioned as a potential problem. This is the individual who goes from job to job performing only radiography. Generally there are no records maintained on this individual. He is quite likely to receive a dose in excess of 5 rem in a one year period, but not at any single company. Thus there is no control over this person's exposure. Since there is considerable employment turnover at this firm, roughly 50% of these transient radiographers may come in and out of the firm in any one year period.

2. Impact of Reduction In Accumulated Exposure Limit

If records were easy to obtain, this proposed guideline would not be a problem. In fact, the highest exposure accumulated entirely at the case study firm is approximately 5 rem, for a 20 year employee. However, it is difficult to obtain records from previous employers, particularly from small firms. Hospitals are also non-responsive. Utilities are quite responsive.

When records from previous employers are unavailable, it is necessary to assume the maximum - 5 rem/yr. (15 rem/yr for exposures incurred prior to 1961). Concern was expressed about the limit if the records are unavailable and it is necessary to assume the maximum. A perspective employee who is over 40 years of age and is unable to produce a record of prior exposure might not be able to obtain employment involving radiation exposure.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

The only time that the hand may receive an exposure higher than the whole body is during source retrieval. For the entire company, this may occur as many as ten times annually. If it looks like the retrieval may be difficult, involving significant potential for exposure, the Radiation Safety Officer is consulted. Another individual may be called in to retrieve the source who can afford the dose. Exposure to the hands during the retrieval operation is not known because ring badges are not routinely worn.

The loading of the source into the projector does not involve extraordinarily high exposures to the hand. In a well-designed projector, there is no higher radiation flux at the entry point of the source than at the other surfaces of the projector. There may have been problems leading to hand exposures on the old Budd cameras (with certain types of "pigtails"), since it was possible for the source to be located close to the edge.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

There were no exposures in excess of 1.5 rem in 1980 and it looks like there will be two in 1981. In 1978 and 1979, approximately 4% of the workers badged received exposures in the range 1 to 2 rem. Therefore, it is not clear if exposures to radiographers in this firm are "anticipated" to exceed 1.5 rem annually.

There are two types of contracts that could lead to annual exposures in excess of 1.5 rem. The first is a long-term job on a construction project, in which some radiographers must be present (by virtue of their experience) over the entire duration of the contract. At present, there are two ongoing jobs of this nature. The second involves radiography at an active nuclear power plant, for which there are several ongoing contracts. Here the problem is the background radiation from the plant itself. Only certain individuals who have gone through the security screening and have had the requisite training can fill these slots. Of course, at the plant, these individuals are under the cognizance of the utility's radiation protection program, as well as that of the case study firm. If a radiation protection professional were required, he/she would no doubt be supplied by the utility.

If professional radiation supervision were required in the field, an average of 10, and possibly as many as 20 of them could be required at any one time. This is how many teams are likely to be in the field. However, the opinion was expressed that these radiation protection professionals would accomplish little in the way of reducing exposures for this type of operation.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

From the exposure data compiled over the past three years, a small percentage of radiographers received exposures in excess of 0.5 rem (3 to 10 %). Therefore, it would probably be prudent to "anticipate" exposures in this range.

Personnel monitoring is currently being performed for all radiographers and radiographer's assistants. Moreover, the supervision requirement in this range is currently being performed by the Radiation Safety Officers. However, none of the RSO's is equivalent in background and experience to a health physicist. Therefore, to satisfy the supervision guideline, a radiation protection professional would have to be retained as a consultant. Alternatively, the state health physicists or those of the source vendors could be called on.

The opinion was expressed that a health physicist could be beneficially used to advise on shielding requirements and biological effects. However, unless the individual also had considerable experience in radiography, he/she would be unable to assist in writing or altering procedures. Moreover, if it were necessary to retrieve a source, a health physicist would be of limited usefulness.

6. Impact of Training Requirements

The current program of instruction for radiographers includes a topic on the biological effects of high levels of exposure. However, instruction on long-term stochastic effects is not included. Currently, 40 man-hours of each student's time and 20 man-hours of instructor's time are spent in training. If instruction on long-term, low-level effects of radiation were to be included in the curriculum, student time would be increased by 10% and that of the instructors by roughly 10%. The average salary level of the instructors is approximately $25,000/year.

7. Impact of the Guidance for Protection of the Unborn

At present, one radiographer and one radiographer's assistant are females (both of child-bearing age). The firm has not as yet formulated a policy relative to radiation exposure of pregnant woman. If a regulatory requirement were to be imposed on the firm in this area, voluntary guidance would be preferable.

8. Impact of Internal Exposure and Combined External Exposure Guidance

Only sealed sources are used by the firm. Thus there exists no potential for internal exposures.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/Yr.

Although there were no exposures in excess of 1.0 rem last year, the imposition of a 1.5 rem RPG would pose a problem for this firm. In both 1979 and 1980, there were four exposures in excess of 1.0 rem, and it appears that there will be 3 - 4 in 1981. Thus a limit of 1.5 rem would be too close for comfort.

The area of the business that might suffer most significantly from this reduced RPG would be the work at nuclear power plants. It is likely that this line of work might have to be dropped if the reduced RPG were to be imposed. At present, roughly 10 individuals, each earning approximately $20,000/year, are involved in this work.

C.2 SMALL CONTRACT INDUSTRIAL RADIOGRAPHER

This small firm is located in the outlying suburbs of a large metropolitan area. The firm performs non-destructive testing (NDT) for clients, largely on a time-and-materials' basis, and is predominant in its geographical area. It has expertise in ultrasonics, dye penetrant, magnetic particle, and radiography. Approximately 60% of the radiography utilizes radioisotopes (largely Ir-192), the remainder is X-ray. The firm is licensed by an Agreement State, and also by the NRC (for out-of-state work).

Equipment is available for 5 - 100 Ci sources, 2 - 50 Ci sources, and 1 - 18 Ci source. Currently four sources are being used, all Ir-192, ranging in activity from 28 Ci to 90 Ci. Six X-ray units are operable, ranging in output from 140 kV to 260 kV. Because of the bulk and set-up time for X-ray radiographs, radioisotopes are preferred. However, X-rays must be used for thin sections, or light-weight metals, such as aluminum. An alternative to X-rays is a thulium radioisotope source, but this is seldom used because of the short (roughly 30 day) half-life and the delivery time. Because of the higher energy gamma ray, Co-60 is sometimes used instead of Ir-192 for thick, or heavy sections. However, this is avoided if possible, because of the weight of the projector.

The firm currently employs 15 individuals. These include three senior management personnel, two of whom are level-3 radiographers, three level-2 radiographers, eight level-1 radiographers (basically trainees), and one clerical individual. The salary for a level-1 radiographer is approximately $4.00/hour. Level-2 radiographers earn between $7.50/hour and $10/hour. Level-3 radiographers can earn considerably higher than $10/hour; they are qualified to write NDT procedures. One of the level-3 radiographers also serves as the Radiation Safety Officer.

There are a few national and international NDT companies that are quite large (in excess of 100 radiographers) and perform testing under contract for others. Many of the large architect-engineering firms, construction firms, and power plant component vendors have large in-house NDT departments. It is estimated that about 50% of NDT is performed under contract with firms that specialize in NDT. Most of the NDT firms, however, are "gypsies" that literally live out of suitcases; some have as few as 2 to 3 employees.

The NRC has recently made it difficult for the gypsy firms by pressuring them to have at least two individuals at a site. This has been standard practice at this firm since its inception.

Each technician who starts out at this firm receives a formal training course the first two days on the job. The course content is in accordance with 10 CFR 34, Appendix A. It includes several hours of training in radiation protection, including the short-term biological effects. After this course, each prospective employee must pass an examination to demonstrate that he/she has mastered the material. It is felt that the most important questions on this examination are the following:

1. What do you do if the radiographer becomes unconscious while a radioisotope radiograph is in process?
2. How do you retract the source?

Additionally, the Radiation Safety Officer frequently makes spot checks of personnel on-the-job to see that they are abiding by safety procedures.

The surface dose rate of a typical projector containing 100 Ci of Ir-192 is approximately 0.15 R/hour. The projector weighs approximately 45 pounds. The source is typically out of the projector for a period of 30 seconds to 5 minutes. Occasionally, for a thick section, the exposure time may be as high as one hour. It is standard procedure at this firm to collimate the source, using a lead pig. This not only provides a better source for radiography, but gives a factor of ten attenuation of the source in the event that it must be retrieved manually. During the exposure, the radiographer must remain outside of a roped-off area which marks the 2 mr/hour isodose line. No protective clothing is worn.

It is company policy to provide a film badge to each employee, including clerical personnel. In 1980, 26 people were provided dosimeters, four of whom received no measurable exposure. The average annual exposure was approximately 0.25 rem, and the maximum was in the range of 1.0 to 2.0 rem. Two individuals were exposed to the maximum. The exposures were comparable in 1979, although in that year one individual received an exposure in the range of 2.0 to 3.0 rem. In all cases, the certified radiographers received the highest doses.

1. Impact of Reduction in W.B. RPG

Over the years, this firm has been working under a quarterly limit of 1.25 rem. Only once in its 14 years of operation has this limit been exceeded. No one has ever been exposed in excess of 5.0 rem in any calendar year. Therefore, under the current operating mode, and given no extraordinary circumstances in the future, this guideline would involve no extra costs to the firm.

However, it is felt that this guideline would eliminate some of the firm's flexibility in the future, resulting in some unquantifiable costs. If, for example, the firm should be awarded a large power plant contract, the load on the existing radiographers could be very high. Under such circumstances, it would not be unusual to process 50 radiographs in one night. Each of these could involve an exposure to the radiographer as high as 1 mr. The limit could be exceeded if 100 shifts like this were experienced in one year. A similar high exposure situation could occur if a large operating nuclear power plant job were obtained. Here, high exposures could be incurred by the staff from the plant itself while waiting to perform radiographs.

Up until now, this firm has not been busy enough to experience such high loads. But an optimistic growth scenario could easily result in such a load. Moreover, it takes approximately two years to train a level-2 radiographer. Thus, such a high load on existing staff would be unavoidable during high growth periods.

Another scenario that concerns top management is that involving the retrieval of a loose or stuck source. A bare source can provide dose rates as high as 500 rem/hour at 1 meter! Over the past several years, sources had to be retrieved on two occasions. In neither of those cases did the exposure to the senior individual who retrieved the source exceed 0.1 rem. However, this was "lucky", and it is felt that as much as 5 rem could be received in the event of a difficult retrieval. In that case, this individual would be unable to perform his senior management role over the remainder of the year, resulting in a financial disaster to the firm.

2. Impact of Reduction in Accumulated Exposure Limit

The highest accumulated exposure to any individual in the firm is 12 rem, obtained over an active professional life of 30 years. The second highest accumulated exposure is approximately 6 rem, obtained over 20 years. Therefore, given the current operating mode, this guideline would involve no extra costs to the firm.

However, concern was still expressed about the potentially restrictive nature of this guideline.

An extremely busy radiographer could easily receive 3 rem annually. This guideline would restrict the active work life of this individual to approximately 30 - 35 years. Admittedly, it would be unusual for an individual to remain active for this length of time. However, it would be desirable to provide a 40 - 45 year vista for young people entering the field.

Possibly a technological breakthrough could develop over the next 30 years which would reduce the unit exposures in radiography. The most likely breakthrough would be the substitution of ultrasonic examination for radiography. Ultrasonic inspections are slowly gaining acceptability.

A concern was expressed about the enforcement of the existing 5(N-18) accumulated exposure limit. The validity of existing data was questioned. A number of individuals who perform radiography for large firms moonlight on the outside. Their outside exposures are generally not entered into the data bank for either accumulated or annual exposures. (They do not like to tell their employer that they are moonlighting!) It was felt that a national data bank is the only way to enforce accumulated exposure limits.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

There should be no costs to this firm from this guideline. There is no reason to believe that the lens of the eye receives an exposure in excess of the whole-body dose. One operation does expose the hand to a significant dose. This involves the connection of the source to the cable of the projector. The streaming of radiation out of the projector has been measured to be approximately 1 rem/hour. Based upon the estimated time to connect the source to the cable (less than 30 seconds) and the number of times this operation is performed (as high as three times per shift), an individual could receive an exposure to the tips of the fingers as high as 2 - 3 rem annually. This is well within existing guidance.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Any of the radiographers could receive annual exposures in excess of 1.5 rem. Moreover, each time that a radiographer goes out on a job, there exists the potential for that individual to receive a significant contribution to that annual exposure. The firm owns three mobile darkrooms, and it is not unusual for two remote jobs to be going on simultaneously. Therefore, this guideline requires radiation protection supervision at each of these remote sites.

Although a certified radiographer is highly trained and experienced, he is clearly not a health physicist or its equivalent. The most experienced individual in the firm in the principles of radiation safety is the Radiation Safety Officer. He has 20 years of experience in radiography, and has taken two formal courses in radiation safety, one administered by the Navy. Nevertheless, he could not pass the health physics' certification examination without significant additional training, and his background and experience are not equivalent to a certified health physicist.

Therefore, two certified health physicists might have to be hired full-time to satisfy this guideline.

The opinion was expressed that a health physicist would have little to do at a site. Even if a source retrieval were required, an experienced radiographer (probably level-3) would have to map out the retrieval operation. Two survey meters and two individuals are presently available at each remote job. If a retrieval operation cannot be performed easily, either the projector vendor or the State are called in.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

This guidance requires individual dosimeters and records, and professional radiation protection supervision to assure exposures are justified and ALARA. Every employee is monitored and the film badges are processed monthly; thus the former guideline is clearly satisfied. A supervisor does assure that exposures are justified and ALARA; however, as discussed earlier, he is not a radiation protection professional. The individual who performs this function is the Radiation Safety Officer of the firm. Each time a new procedure is carried out in the field, he accompanies the crew and sets up the procedure. He is completely familiar with existing NDT procedures (he wrote many of the procedures) and with radiation fields for existing radiographic techniques. For a specific job, he reviews with the field crew the tradeoff between various NDT techniques.

It is estimated that the Radiation Safety Officer spends between 20% and 50% of his time on radiation safety activities. (Management provided the high estimate.) However, he is not a professional in the field of radiation safety. Therefore, a consultant would have to be called in to satisfy this guideline. A rough estimate of the costs is 14 days at $300/day (both of these may be low estimates). Furthermore, the consultant would have to be available for unscheduled and off-hour work.

6. Impact of Training Requirements

As discussed earlier, the first 16 hours of each technicians' on-the-job time is spent in training. NRC establishes the requirements. An additional 24 hours of formal training is required for an aspiring radiographer. Although radiation protection principles are emphasized, only acute and prenatal biological effects are covered. Adding latent effects would require approximately an additional 1/2 hour of instruction. For the number of existing employees, this would cost approximately $200. This does not include the time required for the Radiation Safety Officer to review this material.

7. Impact of the Guidance for Protection of the Unborn

Currently three female technicians work for the firm (one training to be a radiographer), only one of whom is fertile. She has been instructed to inform management should she become pregnant, in accordance with NRC Regulatory Guide 8.13, in which case she would be removed from tasks involving the exposure to radiation. Thus, the firm is currently operating within the guidance of Alternative a.

This firm would have no problem with Alternative b, in which a woman of child-bearing age could voluntarily remove herself from tasks involving exposures in excess of 0.2 rem/month. The company is small enough so that no female employee would use this as an excuse to avoid work. Therefore, if a female were legitimately concerned about potential exposure to the fetus, she would be allowed to express this concern to management, in which case she would be removed from tasks involving radiography.

Alternative c would be unfair to the woman. If removal from radiation fields were to be mandatory, females of child-bearing age would not be hired. It turns out that the one fertile female on this firm's staff is highly motivated to do field radiography, despite the fact that she was hired as a laboratory technician. It is expected that she would be very upset, and would consider it to be an infringement on her civil rights, if she were pulled from radiography and not permitted to go out in the field. This would limit her potential income as well as her ambition.

8. Impact of Internal Exposure and Combined External Exposure Guidance

The firm uses only sealed sources. Thus, there exists no potential for internal exposures.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/year

A reduction in the RPG to 1.5 rem/year would involve a substantial cost to the firm. Although only three individuals were potentially exposed above 1.5 rem over the past two years, the imposition of a limit at 1.5 rem/year would inhibit the growth of this company. At present, only three of the personnel are qualified radiographers. These are the personnel who receive the high exposures. There is no way to substitute other personnel for those radiographers, or to hire additional radiographers off the street. Radiographers are trained in-house over a two-year period.

This firm has had poor luck with radiographers hired from other firms. In the larger firms, individuals are too specialized. In a firm of this size, a radiographer must be a "jack-of-all-trades." The only way to gain this experience is through in-house training. Therefore, the imposition of this lower RPG would reduce the existing business level somewhat (in order to assure that the existing radiographers do not exceed an exposure of 1.5 rem) and preclude future growth.

C.3 IN-HOUSE RADIOGRAPHER

This huge manufacturer of steel and steel products had sales in excess of $7 billion and 84,000 employees in 1981. Radiography is performed at 8 locations that have a total employment of 17,000. These facilities manufacture ships, tanks, large diameter pipes, castings and welded structures.

The shipbuilding facilities use both X-rays and isotopes for the inspection of pressure piping, hulls, and decks. The three facilities, each of which employ roughly 20 - 25 full-time non-destructive testing (NDT) personnel, have approximately 12 X-ray machines and 12 radioactive sources (mostly Ir-192, some Co-60). Radiographers (who also perform other types of NDT) work in teams of 2 -3 man crews, supervised (part-time) by additional supervisory staff and a manager.

There are several tank and welded structural fabrication facilities which contain a total of approximately 30 X-ray tubes (200 - 300 KeV) and one 2 1/2 MeV Van de Graaff accelerator. The X-ray machines at these facilities are likely to be manned by operators (one or two steps above entry level), rather than radiographers.

Large diameter pipes are manufactured at a single facility that has approximately 15 X-ray tubes. Most of the radiography is performed on a production line basis using fixed-station fluoroscopes and X-ray machines (150-300 KeV). Approximately 120 personnel are involved.

Dosimetry is performed in-house using TLD's, read monthly. Approximately 600 personnel are monitored, roughly 300 of which are technicians who maintain thickness gauges. Exposures to these personnel are usually insignificant (well under 100 mrem per year). In addition, approximately 50 personnel in the various medical departments, 20 laboratory personnel, and 30 researchers are monitored. This leaves approximately 180 workers involved in radiography, approximately one-third of which are actually radiographers.

The 1981 exposure data for workers involved in radiography are given in the Table. They are broken down into the three categories of facility described earlier. Most of the exposure in the shipbuilding category is from radioisotopes.

WHOLE-BODY EXPOSURE DISTRIBUTIONS FOR 1981

	Numbers of Individuals		
	Shipbuilding & Repair	Tank Fabrication	Pipe Fabrication
Less than 100 mrem	19	10	82
100 - 250 mrem	6	2	31
250 - 500 mrem	3	1	5
500 - 750 mrem	7	1	0
750 - 1000 mrem	10	0	0
1000 - 2000 mrem	1	0	0
Greater than 2000 mrem	0	0	0

It is felt that the exposures experienced at this firm are typical of in-house radiography nationwide. Exposures at airline manufacturing facilities may be somewhat lower, whereas boiler manufacturers are likely to expose personnel to somewhat higher doses. Approximately 50% of all radiography nationwide is estimated to be performed in-house.

Radiation safety at this firm is the responsibility of the Corporate Health Physicist. He is a certified* health physicist with over 15 years of experience. He reports to the Corporate Director of Noise and Radiation Control, who in turn reports to the Manager of Environmental Health, who reports to a Vice-President in charge of Industrial Relations. The Corporate Health Physicist is assisted at the corporate level by a radiologic technician who handles the personnel monitoring program, calibrates the survey instruments, and performs some field work.

The Corporate Health Physicist develops the corporate radiation protection program and audits the individual facilities periodically to determine compliance with this program and with the regulations. His interface at the operating unit is called a Radiation Safety Coordinator. This individual may be an industrial hygienist, a safety engineer, a chief radiographer, or a personnel man. Although the Radiation Safety Coordinator does not report to the Corporate Health Physicist, there is a "dotted line" relationship.

All industrial hygienists, some of the safety engineers, and some of the Radiography supervisors attended a 40-hour course in radiation safety conducted by the Corporate Health Physicist approximately four years ago. Additionally, all of the radiographers at the shipyards and some of the tank fabrication facilities attend an annual 20-hour course in radiation protection, including a portion on acute and chronic levels of risk. When a new employee who will be involved in radiography is hired at the shipyards, he is given a 1 1/2 hour lecture on radiation safety by his supervisor, and a copy of a pamphlet describing the regulations, monitoring policy, etc.

Radiation protection instruction at the remaining tank fabrication facilities is spotty. Periodically, the Corporate Health Physicist conducts a course on radiation safety. This is usually instigated by a change in management at the facility. Little, if any instruction in radiation safety is provided by the Coporate Health Physicist at the pipe fabrication facility. Approximately 18 months ago a course was conducted on successive Saturdays, but attendance was voluntary.

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*Six years of health physics' experience is a prerequisite to certification. Prior to the certification examination, this individual took a night course (one night a week) sponsored by the Health Physics Society for 4 months. During this time, approximately 2 hours a day of independent study were necessary.

Radiographers at the shipyards receive a base salary of $20,000 per year, although they can earn as much as $35,000 with overtime. The work at the shipyards, however, tends to be dirty, and involves a lot of odd hours. At the tank fabrication facilities, where the conditions are somewhat better, the operators of the X-ray units typically earn $8.00 - $15.00 per hour.

1. Impact of Reduction in W.B. RPG

There would be no impact from this change in the W.B. RPG, even if the business climate were to improve substantially. Even though more pictures may be taken in the case of in-house radiography, exposures are typically lower than for contract radiography because more time is generally taken for set-up. Pressures are lower; incentives to radiographers in the contract firm are related to the number of pictures taken, whereas the in-house radiographer is on salary plus overtime (if the business level is low, overtime is unavailable).

2. Impact of Reduction in Accumulated Exposure Limit

There is very low turnover in this firm. It is not unusual for a radiographer to have 20 years of experience with the firm, and some employees have been with the firm as long as 40 years. Because of the relatively low exposure levels, real accumulated exposures are considerably less than 100 rem, and the establishment of a limit at this level would pose no problem for this firm. However, because several workers were in this field prior to 1961 and their exposure records were unavailable (making it necessary to assume 15 rem/year), the apparent accumulated exposures for a few individuals exceed 100 rem.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

In industrial radiography, exposures to extremities are not expected to be significantly higher than whole-body exposures (including eye lens). Thus there would be no impact at this firm from the proposed hand limits.

Some concern was expressed, however, about the omission of limits to the forearms, feet, and ankles, which were specifically addressed by the FRC guidelines. In the absence of such guidance, the regulators may either establish their own limits or set the limits to these extremities at the whole-body limit (5 rem/yr). The establishment of a 5 rem/yr. limit to these extremities would be foolhardy because they are invariably exposed to higher doses than the whole body.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Although there were no exposures in this range in 1981 (the highest exposure was 1.4 rem), exposures would be "anticipated" in this range at the shipyards if business conditions were to improve and they went into full production. In fact, roughly six individuals, or approximately 20% of the radiography workers, would be expected to receive annual exposures in excess of 1.5 rem. However, exposures are built up gradually and no single task makes a "significant" contribution to the annual dose.

If radiation protection supervision were required, only one supervisor would be required during the day. During each of the two night shifts, however, two, or as many as three supervisors would be required because most of the radiography is performed at night. Presently, a supervisor supervises each radiography team, but he is only present during the set-up of the job. A manager is present during the day shift only.

There are at least two individuals on each radiography team. The team leader is responsible for complying with regulations and for performing such surveys as are necessary to assure that area dose rates and individual dose limits are being satisfied.

However, there is no individual at the unit level with background and experience equivalent to that of a health physicist, even though several individuals at some of the facilities are quite knowledgable in radiation protection. As many as four individuals at the shipyards know a great deal about radiation monitoring, shielding, etc., although none of them has a college degree.

The contribution of a professional health physicist during the actual work would be minimal. Even in the event of a stuck source, an experienced radiographer and his supervisor should be able to handle the situation. A contribution could be made by having a supervisor on hand who is not production oriented, however, this individual would not have to be a health physicist. One of the airline manufacturers actually employs individuals (non-radiographers) who monitor full- or part-time while radiography is being performed.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

Both the individual monitoring and the supervision requirements of the guidelines are currently being satisfied at this firm. The Corporate Health Physicist performs periodic surveys and specifies for the operating units, radiation protection guidelines consistent with the regulations and with the ALARA principle. The implementation of this program is carried out by the local Radiation Safety Coordinators and the performance of the operating units is periodically audited by the Corporate Health Physicist.

6. Impact of Training Requirements

The requirements on instruction in radiation protection principles and levels of risk is essentially being carried out at all units except the pipe fabrication facility. Here, approximately 120 workers, many with no high school education, would require 30 - 40 hours instruction. The facility operates on three shifts. The instruction could be given in approximately ten sessions. The annual salary of the instructor is approximately $_______. After all of the existing workers were trained, the program could be maintained by continuing these sessions twice a year, since the employee turnover rate is low.

7. Impact of the Guidance for Protection of the Unborn

The firm is currently operating under Alternative a, although the number of women employed in radiography is low. There are 10 females in radiography at the pipe fabrication facility, one in tank fabrication, and none at the shipyards. Thus there were no women in 1981 with exposures in excess of 500 mrem.

Currently, females are presented with the NRC Regulatory Guide on the Unborn and view a film produced by Radiation Management Corporation. Although a female, in theory, can remove herself from work involving radiation exposure if she is concerned

about exposing the unborn to 500 mrem, in practice another job may not be available at the same pay rate.

The potential for exposures in excess of 0.2 rem per month is essentially zero, even if business levels were to pick up. Moreover, there are no women radiographers in the shipyards, at present. Therefore, Alternative b, for all practical purposes, is moot. At present there are no woment with exposures in excess of 500 mrem; however, if one were hired at a shipyard, the likelihood becomes real. While the radiographers are part of the welding department (they are not "brought-up-through the ranks"), they are hired from throughout the yard or "off the street". So it is likely that under full production, a woman (women) could be hired.

8. Impact of Internal Exposure and Combined External Exposure Guidance

All of the radioisotopes used in radiography are sealed sources, so there is no potential for internal exposure.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/Yr.

The only operation that would be affected by a reduction in the whole-body RPG to 1.5 rem would be the shipyards, and only at full production. As discussed earlier, it is estimated that at full production approximately six radiographers would receive doses above 1.5 rem. Exposures could be reduced below 1.5 rem if an additional two to four radiographers were hired. This would no doubt increase collective exposure.

D.1 MANUFACTURER AND DISTRIBUTOR OF CLINICAL AND RESEARCH RADIOISOTOPES

This manufacturer and distributor of radioisotopes specializes in research and clinical diagnostic products for the life sciences. Employing 1,700 at three production sites in a major metropolitan area, the firm services a large fraction of a $175M market. There are roughly five major competitors.

In the research products line, chemicals are labeled with C-14, H-3, S-35, P-32 (all beta emitters), I-131 and I-125 (gamma emitters). Additionally, small calibration sources (less than 100 mCi) are manufactured from as many as 100 isotopes. The predominant radioisotopes in the clinical diagnostics' line are Mo-99 (for generation of Tc-99m), Tl-201, Ga-67, and Xe-133. Isotopes are made by nuclear transmutation using four cyclotrons and several outside reactors and accelerators. A linear accelerator is being constructed to supplement the cyclotrons.

The firm does not manufacture large, multi-curie sources for purposes of irradiation or radiography (i.e., Co-60, Ir-192, etc). These are all reactor-produced sources. This industry, dominated by approximately five firms, grosses approximately $25M annually. A transportation industry, mostly truck, services both industries. An estimated 200 - 500 individuals who transport radioisotopes may be receiving non-negligible exposures. For example, there are an estimated one million shipments of Mo-99 generators annually.

Another segment of the radioistope manufacturing industry makes tritium signs, smoke detector sources, etc. This industry incorporates a number of small firms and has few employees.

Of the 1,700 employees of this firm, there are roughly 1,300 monitored for radiation exposure, 700 of whom are potentially exposed and 400 who are "hard core" (people handling many gamma isotopes in Curie and multi-Curie amounts) radiation workers. The monitoring policy is two-fold. First, badges are provided to all employees who have the potential to receive in excess of 25% of the limit (internally established at 5 rem/yr). Second, other employees who will receive less than 25% of the limit are also monitored. For example, at one of the production facilities in which a large number of gamma-emitting sources are manufactured, everyone who enters the facility is monitored. External dosimetry is performed with TLD's and electrostatic dosimeters, which are read weekly by in-house personnel. Individuals who are potentially exposed to neutrons are also supplied with neutron-sensitive film badges which are processed by an outside vendor. The in-house dosimetry costs approximately $30,000 per year, higher than if it were done on the outside. However, the added flexibility is worth the additional costs. The exposure distributions for the most recent entire year (1980) are compared with the results from 1977 in the attached Table. In 1978, 69 individuals received exposures in the range of 1.0 - 2.0 rem, 49 in the range of 2.0 - 5.0 rem, and 7 in excess of 5.0 rem. In 1979, 56 individuals received exposures in the range of 1.0 - 2.0 rem, 33 in the range of 2.0 - 5.0 rem and 7 in excess of 5.0 rem. There has been a noticable downward shift in the number of high exposures over the past several years, particularly in excess of 5 rem. Also, the number of exposures in excess of 1.0 rem has decreased over the past four years from approximately 20% of the total number of monitored employees to less than 10%.

The exposures to truck drivers who are employed by this firm are also of interest. Of the 19 drivers who handled radioactive materials in 1979, the average whole-body exposure was approximately 1.0 rem and the maximum exposure was 1.7 rem. These were down from an average of 1.3 rem and a maximum of 2.7 rem in 1978. Wrist exposures to truck drivers were approximately 10 - 20 percent higher than whole-body exposures.

Most of the higher exposures are experienced in four activities. These are production of Mo-99 generators, production and maintenance on accelerators, waste management, and transportation of radioisotopes.

An extensive internal dosimetry program is also conducted. Approximately 600 employees are given weekly urinalyses. This is the best test for H-3 intake. Weekly breath analyses on approximately 100 workers are conducted to detect for C-14. Approximately 50 workers who come into contact with radioiodine are given weekly thyroid measurements. Annual whole-body counts are conducted on appoximately 400 employees who handle gamma-emitting nuclides. Approximately 6 - 7 of these 15-minute counts are conducted daily. Finally, special samples are sent out for analysis for those workers potentially exposed to Ni-63 and Am-241.

The company samples air concentrations of radionuclides at approximately 1,000 locations. The samplers consist of membrane filters, impingers, charcoal filters, and real time monitors.

Whole-Body Exposure Distributions for the Years 1977 and 1980

Exposure Range	Number of Individuals	
(Rem)	1980	1977
None Measurable	800	328
Less than 0.10	250	81
0.10 - 0.25	80	47
0.25 - 0.50	50	41
0.50 - 0.75	35	25
0.75 - 1.0	23	21
1.0 - 2.0	67	55
2.0 - 5.0	65	82
< 5.0	1	11

There are approximately 40 individuals in the radiation safety office, roughly 10 of whom are dedicated full-time to the management of radioactive wastes. Four of the professionals have master's degrees (two in radiological health); however, only one of these individuals is partially certified in health physics. Of the remaining staff, academic backgrounds range from high school education to bachelor's degrees. Approximately 15 individuals have bachelor's degrees, mostly in the physical sciences. The annual budget of the office (exclusive of waste management) is approximately $1M. This budget has more than doubled, as a percentage of sales, over the last five years.

The Radiation Safety Officer reports to the Director of Environmental Control, who in turn reports to the Vice-President for Administration. There are three industrial hygienists in the office of the Director of Environmental Control, one of whom is a certified health physicist.

Salary scales for the laboratory technologists range from approximately $12 to $20 per hour. Supervisors can earn as much as $40,000 per year. The salary range for health physics' personnel is $25,000 to $40,000 per year. Health physics' support personnel earn from $17,000 to $27,000 per year.

Training is the responsibility of line supervisors. All new employees get a Radiation Protection Handbook, which describes the internal management structure for radiation protection, the required procedures for working with radioactive materials, the regulatory limits, and the procedures in the event of emergencies. NRC Regulatory Guide 8.29 will be incorporated in this manual. Additionally, new employees attend 16 hours of lectures on safety, 10 hours of which are devoted to radiation safety. Roughly one hour of the 10 is devoted to levels of risk from radiation, corresponding to the material in Regulatory Guide 8.29. After attending the course and reading the handouts, new employees must pass an examination, the level of which is geared to the job to be performed by the worker.

Additional safety instruction is provided in annual brown-bag lunches tailored to each of the departments. Although attendance is not mandatory, 95% attendance is typical (the lunch is provided by the company). Additionally, 3-hour workshops are frequently conducted for specialized groups of people. Finally, staff members of the Radiation Safety Office undergo continual training. For the accelerator group, this occupies approximately four hours per week.

1. Impact of Reduction in W.B. RPG

This firm is currently operating under a self-imposed 5 rem annual limit. However, if the regulatory limit were to be reduced to 5 rem, it would be necessary to impose a buffer to assure compliance with the regulation. It is estimated that a 20% buffer would be satisfactory. Thus, if the W.B. RPG were reduced to 5 rem/yr., this firm would operate internally with a 4 rem/yr. RPG.

Currently, warning levels are established at various fractions of the RPG, dependent on the worker's assignment. At 2 rem/qtr., a worker is pulled out of the laboratory. If the proposed 5 rem RPG were imposed, the new warning level would probably be set at 1.0 rem/qtr. In 1980, 16 workers exceeded 4 rem/yr. (In 1981, this number was decreased to 2.) It is estimated that as many as 6 workers exceed the one rem level each quarter. These workers are involved in radiopharmaceutical production, accelerator operations and maintenance, and waste engineering.

In order to comply with a 1.0 rem quarterly limit, the preferable solution would be to apply new engineering changes. This may be difficult, however, since a number of recent engineering changes have already been imposed — new transfer equipment in the hot cells, for example. An increase in the number of radiation safety workers might also accomplish this. For example, in a period in which radiation safety expenses increased from approximately one to two percent of sales, the percent of exposures in excess of 1.0 rem has gone down by a factor of roughly two. A final method for lowering the quarterly exposures would be that of increasing staff. Possibly 15 new people would do it. However, this would have the undesirable side effect of increasing collective dose — possibly by as much as 10%.

2. Impact of Reduction in Accumulated Exposure Limit

There is some concern about reduction in flexibility due to this proposed guideline. Currently, there are approximately six people in the company who have more than 100 rem. The maximum lifetime exposure accumulated in the employ of the company, however, is approximately 50 rem. If a new employee started out at age 18, he could potentially hit the limit in 25 years. However, this is unlikely under normal conditions. It is the accidental exposure that is of concern. One hundred and fifty rem would be a more reasonable limit, providing more flexibility.

It was also mentioned that difficulty is sometimes encountered in obtaining records from previous employers.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

There would be expected to be no impact from the proposed 50 rem per year hand limit. Approximately 400 employees routinely wear wrist badges and 300 wear ring badges. The highest recorded hand exposure was 19 rem, obtained by an accelerator worker under accident conditions. A more typical high annual exposure to the hand is 12 rem.

The proposed limit on exposure to the eye lens would indeed cause a problem. From independent checks using TLD's on the rims of glasses, the exposure to the eye lens is roughly a factor of 1.8 higher than the measured whole-body exposure for accelerator workers. Therefore, in the current operating mode, there would be some overexposures to the eye lens. Moreover, the firm would incorporate a 20% buffer, as in the W.B. exposure limit discussed earlier.

There are approximately 15 workers who perform maintenance on accelerators. All of these personnel receive whole-body exposures in the range of 1.8 to 2.5 rem. Therefore, one would anticipate eye lens exposures in excess of 4 rem. However, estimated exposures are so close to this limit that the proposed guidance could probably be met by tighter monitoring and auditing.

Personnel could wear lead-impregnated glasses, which at the gamma ray energy levels involved (approximately 1 Mev), would provide an attenuation of roughly 1.2. However, it is difficult to wear these glasses for accelerator maintenance because vision is slightly impaired. Face shields would be totally unacceptable.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

As seen in the Table, as many as 10% of the monitored employees may have been in this range in 1980 (an estimated 9% in 1981). Five activities would contain essentially all of these personnel. The first is accelerator production and maintenance. An exposure in excess of 300 mrem could be obtained during an accelerator maintenance task. The four cyclotrons are at most, 100 yards apart (roughly three minutes). They operate on 24-hour shifts. During the day shift, maintenance may be performed on all four accelerators simultaneously. At night, one individual could oversee all operations. Thus, six individuals would be required for accelerator supervision. (At present, monitoring is performed on a spot-check basis.)

The production of Mo-99 generators is performed in one room on one shift. The eight personnel working in this room could all receive annual exposures in excess of 1.5 rem, although these exposures would be accumulated relatively uniformly over the course of a year. One supervisor could cover this room. Currently, a technician monitors the area. This individual is not equivalent in background and experience to a health physicist.

Hot waste is handled by approximately 13 workers in one area on one shift. During waste handling, exposures as high as 100 mrem can be received during a single task. This area is currently monitored by a technician. This individual is not equivalent in background and experience to a health physicist.

Approximately 15 workers in the hot processing area can be expected to receive annual doses in excess of 1.5 rem. The exposure, which could be in excess of 100 mrem during a single task, is obtained in transfer of samples and in hot cell decontamination. One supervisor would be required on one shift.

The final group of workers who would be anticipated to receive annual doses in excess of 1.5 rem are the truck drivers who deliver the Mo-99 generators. The company employs approximately 20 drivers, and all of them deliver moly generators. The exposure is received in the process of loading and unloading these sources. At any one time, as many as 300 shipments may be in progress.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

Both the monitoring and supervision requirements of this guideline are currently being carried out by the Radiation Safety Office. Therefore, there would be no costs from this proposed guidance.

6. Impact of Training Requirements

This is currently being carried out, including instruction on levels of risk.

7. Impact of the Guidance for Protection of the Unborn

Approximately 10 to 20 percent of the technologists are women. Most are in the range of 20 to 40 years of age. At one time, if a woman became pregnant, she would be pulled out of the laboratory. This is no longer done, because of women's rights. Now the firm operates under Alternative a. If a woman learns that she is pregnant, she may request of her supervisor a job involving lower exposures. If she decides to stay on the job, she is monitored more frequently. Her total nine-month work period is not to exceed a cumulative dose of 500 mrem (times an administrative safety factor of 0.8).

If Alternative b were promulgated, a study would be performed on exposure levels in areas from which females request reassignment. The data would be turned over to the cognizant supervisor. If it were not possible to maintain levels below 0.2 rem/mo., then the women would be given a leave of absence or told to get another job. There would be no costs above and beyond Alternative a.

If the mandatory provisions of Alternative c were promulgated, a lot of women who would like to choose their destinies would be quite upset. At present, an estimated 10 women (probably of child-bearing ages) are potentially exposed to levels in excess of 0.2 rem/mo. These women would have to be discharged and males would have to be hired in their places.

8. Impact of Internal Exposure and Combined External Exposure Guidance

The routine assay program for estimation of internal exposure levels has been described earlier. The airborne concentration measurements (roughly 1,000 sampling points) are used to determine the need for non-routine assays.

H-3 is the principal isotope that gives significant internal exposures. Last year, four individuals received internal, whole-body exposures in the range of 200 - 500 mrem, 12 individuals received exposures in the range of 50 - 200 mrem, and everyone else received less than 50 mrem from tritium. Every couple of years, an individual may receive in excess of 1.0 rem. The highest estimated internal exposure from H-3 was 1.5 rem. However, the individuals handling tritium do not also receive external exposures.

Measurable exposures are also received from radioiodine. Last year, five people received estimated doses to the thyroid of 0.5 - 1.0 rem, and 200 people received 100 mrem to 500 mrem. The remainder of those working with radioiodine received less than 100 mrem.

Screening is routinely performed for the 100 or so gamma-emitting isotopes. For the most part, internal doses are less than 1 mrem. If measurable body burdens are detected by any assay method, doses to critical organs are calculated. Occasionally, measurable amounts of Se-75, Hg-203, or Co-57 are detected. In one incident, an individual obtained a lifetime dose commitment from Am-241 of approximately 5 rem. There has been no incident in which the estimated internal exposure was greater than 1 rem.

The weighting prescription in the proposed guidelines is not likely to involve additional costs. Nor is the requirement to add internal to external doses. Internal exposures are generally low enough to make no difference in compliance with prescribed limits. However, the mechanics of compliance would no doubt require a computerized accounting system. It is estimated that such a system could be programmed with approximately four person-months of effort.

Concern was expressed about calculating internal dose commitments from measured body burdens for the long-lived nuclides from measurements. The accuracy of the measurements for some of these nuclides may not be sufficient to assure compliance with limits. Of particular concern is Sr-90 (a beta emitter). Although less than five people are potentially exposed and under normal conditions air concentrations are well below MPC's, the concern is about accident conditions. Urinalysis is the conventional bioassay technique. The detection limit is 0.2 disintegrations per minute for Am-241.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

The initial reaction to this guideline is that the firm "would go out of business." Last year, approximately 130 people, or about 10% of the monitored work force, received exposures in excess of 1.0 rem. This year, it is expected that this number will also be approximately 10%. About 35 of the individuals receiving exposures in excess of 1 rem are in the accelerator area. Over the past year, the collective dose in this area has been reduced by 60%, from 130 person-rem to 50 person-rem. Most of the dose in this area is from handling of the target and exposure to the residual induced activity from the machine.

About six years ago, a new handling system was installed on all four machines at a cost of approximately $75,000. A newly designed system might cost about $150,000 for all four machines. This would reduce exposures to approximately 15 of the 35 people who handle targets. The company has R & D programs underway to reduce exposures to the other 20 workers.

One potential drastic measure to reduce exposures in the accelerator area would be to buy another accelerator at a cost of $2.5M. This would reduce the usage factor on the other cyclotrons, allowing more decay time of the short-lived activation products, thus resulting in lower exposures to accelerator workers.

Mo-99 generator production (approximately eight people) is another area with potentially high exposures. Levels have been reduced substantially over the past several years. Levels could always be reduced further, but cost estimates are not available.

Another drastic method to reduce exposure levels below 1.5 rem would be to add about 50 personnel. Costs would run approximately $20,000 annually per worker (plus 35% fringe). Based on experience in the accelerator area, collective dose would increase by approximately 20%.

D.2 MANUFACTURER AND DISTRIBUTOR OF LARGE SOURCES

This firm manufactures high activity Co-60 sources for medical applications (teletherapy) and radiation processing (animal feed, medical supply sterilization, and production of polymers). Additionally, the firms uses its own sources to perform radiation processing, which comprises approximately 50% of its annual $4M sales.

Most of the firm's competition in the manufacture of large sources (1000 to 10,000 Ci) is foreign. (Smaller sources for gamma radiography and instrument calibration are manufactured by a small number of other domestic companies.) In the field of radiation processing, there are a number of domestic competitors; the largest overall market is for the sterilization of medical supplies.

Sources are produced by the irradiation of natural cobalt, encapsulated in stainless steel, in power reactors over a several-year period. Activated sources are shipped back to the firm in casks containing up to 600,000 Ci of Co-60. Sources are stored in a pool and transferred to a hot cell for remote handling. Sources to be used in radiation processing are doubly encapsulated in stainless steel. Sources to be used in teletherapy must be stripped of the original cladding and melted down into a new configuration. The meltdown operations are performed in "campaigns" involving as much as 300,000 Ci. Once the campaign has been completed, the hot cell, which has been contaminated with "hot" chips of cobalt and cladding, must be decontaminated, an operation involving significant personnel exposures.

Hundreds of the sources are configured into "plaques" containing 10^6 Ci to be used for in-house radiation processing. The plaques are transferred to one of two radiation processing cells, where they are stored in pools. Access to the irradiator cells is controlled; the sources are raised from the pools remotely. Accordingly, personnel exposures from normal radiation processing activities are small.

Teletherapy source installers work in teams of two individuals (an installer and a helper). Two teams install 60 to 80 sources annually. Installers, who must be quite skilled and experienced, are licensed.

The firm employs approximately 80 individuals; 30 are directly involved in radiation processing, eight in source production, and six in source installation. Everyone who goes into the plant regularly is monitored for radiation exposure. Monitoring consists of a self-reading pocket dosimeter, a TLD processed monthly, and a TLD processed quarterly. Additionally, a handful of employees wear ring or wrist badges. Whole-body exposures for the year 1981 are given in the Table.

The Radiation Safety Officer, who reports to the president of the firm, has an advanced degree in metallurgy and years of experience in radioisotope production and handling. Two other professionals, one with degrees in physics and nuclear engineering and the other with a Ph.D. in physics, assist the RSO in radiation protection activities. Four technicians perform monitoring and decontamination. A radiation safety committee comprised of three individuals reports directly to the president.

There is no formal training course for new employees, although one is under development. New employees are given a briefing of approximately two hours' duration on the principles of radiation safety. The briefing is conducted informally by the RSO or another of the firm's professionals. There is some discussion of levels of risk, although it is not quantitative.

1. Impact of Reduction in W.B. RPG

The firm has been operating with an internally-imposed RPG of 5 rem/year for the past couple of years, and usually only one individual exceeds this limit each year. Exposures have steadily come down over the past several years; fifteen years ago, several individuals were pushing up against the 3 rem limit each quarter.

Despite the firm's success in operating within the limits of the proposed RPG, there is considerable concern about its establishment as a regulation. This concern relates to the costs of an overexposure, which is felt to be more likely under the proposed RPG. In the history of the firm, there have been three reportable overexposures. Although the measurable costs were high (several thousands of dollars), the intangible costs related to public perceptions are of primary concern. In the current environment of high public sensitivity to radiation, the costs of an incident could be very serious.

WHOLE-BODY EXPOSURES FOR THE YEAR 1981

	Numbers of Individuals
Less than 0.010 rem	21
0.010 to 0.099 rem	33
0.100 to 0.249 rem	7
0.250 to 0.499 rem	3
0.500 to 0.749 rem	3
0.750 to 0.999 rem	2
1.000 to 1.999 rem	10
2.000 to 2.999 rem	5
3.000 to 3.999 rem	0
4.000 to 4.999 rem	0
5.000 to 5.999 rem	1
Greater than 6.000 rem	0

For this reason, the firm would have to operate with an administrative limit considerably below the RPG (possibly at 60% of the regulatory limit) in order to provide a satisfactory margin of safety. This would jeopardize the effectiveness of a couple of key technical personnel, who must be available for unusual circumstances, and who can receive significant fractions of the RPG in a single task.

These concerns are punctuated by a couple of realities in the marketplace. The first is the competition afforded by a foreign supplier who is in a more favorable regulatory environment. The second is the competition afforded by electronic sources of ionizing radiation (in the teletherapy market), which benefit from stricter regulations on radioisotope sources.

2. Impact of Reduction in Accumulated Exposure Limit

The highest accumulated exposure of an employee of the firm is 76 rem; however, most of this exposure was received during this individual's 27 years' employment at a hospital. One of the firm's senior technicians has accumulated 64 rem during his 15 years with the company.

Although it was felt that compliance with the 100 rem limit could be accomplished at minimal costs, some concern was expressed about the potential for career shortening. For example, the subject technician is in his mid-thirties and could conceivably accumulate the additional 35 rem over a seven-year period, thus ending his productive career with the firm in his early forties. (A move to management is not the answer, since management also performs hands-on tasks involving exposure to radiation. In fact, the president frequently performs the initial pass at decontamination of the hot cell.) For this reason, 150 rem is felt to be a more reasonable accumulated exposure limit.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Exposures to the eye have never been measured and recorded. Monitors are normally worn at the waist, so they are no help in estimating exposures to the head or eyes. Pocket dosimeters are occasionally taped to the head. Since it is easier to shield the body than the head during a high exposure rate activity, this is frequently done, resulting in annual head exposures higher, by possibly as much as a factor of two, than whole-body doses. Since there are few repeatable procedures at this facility, occasional monitoring at the eye level would not be the answer.

Hand exposures could also be pushing up against the proposed limit. Source installers and field service personnel wear wrist badges. The highest measured dose was 33 rem, but this was unusually high. In some of the other operations performed at the facility, a spot check has revealed that hand doses may be as high as ten times the whole-body exposure. Handling of waste drums is one of these high exposure activities. If the limit to the hands were to be reduced, more routine monitoring would be required. The costs would be $2.70/month/badge, not including the additional recordkeeping.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Exposures in excess of 1.5 rem/year may be anticipated for personnel involved in three tasks. The first is the installation of teletherapy sources. Six personnel, organized into two teams, are involved. In the course of a typical source installation, an exposure of 50 - 75 mrem is obtained. Source installation requires constant travel, and there is high turnover, particularly for the helpers. The average annual income for an installer is $40,000; a helper may make approximately $30,000 per year.

The second activity involving anticipated annual exposures in excess of 1.5 rem is in source fabrication. Three individuals work full-time in source fabrication and others on the engineering management staff are involved, particularly after a campaign when the hot cell requires decontamination. All entries to the hot cell are carefully mapped out well in advance of the actual work. An exposure as high as 1 rem is normally received on the first entry. Subsequent entries expose individuals in excess of 0.1 rem per pass, and the total for an individual often is the range of 1 rem for an entire decontamination.

The third significant exposure activity is waste handling. Approximately six individuals are involved at one location.

There are no health physicists currently employed by the company. A health physicist was hired a few years ago, but he was subsequently let go after the occurrence of a series of problems. At least three members of the engineering staff, and possibly as many as five, could potentially pass the health physics certification examination, given several months of study.

It was felt that a health physicist would contribute little until he had spent sufficient time at the plant to become intimately familiar with the operations. Until that time, which could be as long as one to two years, he could be a detriment to the operation, particularly if he were required to monitor before and during each Range C task. This could slow down the operations, resulting in higher collective exposures.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

All personnel potentially exposed in excess of 0.5 rem/yr. are currently monitored for whole-body exposure.

The equivalence of the existing engineering staff to radiation protection professionals is discussed, in part, in the previous section. Notwithstanding the background and experience of the existing staff, the Agreement State that licenses this firm does not consider any of the existing personnel to be a radiation protection professional.

The firm retains a medical physicist, who performs a QA audit monthly at a cost of $400. He checks the radiation logs, the procedures, and generally reviews the operations for problems. He does not, however, perform hands-on monitoring or assure that exposures are ALARA.

6. Impact of Training Requirements

As described earlier, each new employee is given an informal briefing of approximately two hours duration on radiation protection principles. This briefing does not include quantitative guidance on levels of risk. However, copies of NRC Regulatory Guide 8.29 "Instruction Concerning Risks from Occupational Radiation Exposure," were recently distributed to all radiation workers, and are given to all new employees.

7. Impact of the Guidance for Protection of the Unborn

The only tasks in which exposures may be received in excess of 0.5 rem over a nine-month period, or in excess of 0.2 rem in any one month, are source installation, source fabrication, and waste handling. Women have never been used for any of these tasks, partly because they all involve heavy physical work. Therefore, there would be no impact at this firm from the provisions of the guidance for protection of the unborn.

8. Impact of Internal Exposure and Combined External Exposure Guidance

Internal exposures to airborne Co-60 are possible during hot cell decontamination. The company has six portable air monitors which are used whenever the hot cell is open. Respirators are routinely worn when airborne concentrations reach 1/30 of the MPC ($3 \times 10^{-10} \mu$Ci/ml).

Although the Derived Air Concentration for soluble Co-60 in the proposed guidelines is lower by approximately an order of magnitude than the existing MPC, this should pose no problem, since the firm is operating under the insoluble limits. The Derived Air Concentrations for insoluble Co-60 are only approximately 10% lower than the existing guidelines.

There is no routine bioassay program. For a number of years, employees were sent to the National Institutes of Health for whole-body counting, but this was discontinued. One instance of intake was uncovered by the routine "frisking" of an employee using a sodium iodide crystal. The employee was subsequently sent to NIH for whole-body counting. It was determined that the employee took in 6 μCi of Co-60 and received a dose commitment to the whole body of 10 mrem. This incident demonstrated the sensitivity of the external monitoring probe to internal deposition.

Routine urinalysis has been considered, but was rejected because of environmental insults and the inability to deal with insoluble material. Routine whole-body counting is too expensive; the number of employees is too small to warrant interest on the part of the companies that provide this service.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/Year

In 1981, there were approximately 15 employees with annual exposures in excess of 1.5 rem. If a lid of 1.5 rem were to be imposed, outside personnel would be brought in to accomplish high exposure tasks, similar to the practice at nuclear power plants. This "blood bank" type of operation would result in a collective dose considerably higher than the 34 man-rem accumulated in 1981 by personnel who exceeded an annual dose of 1.5 rem.

This approach could not be used to reduce the exposures to source installers. There are only a couple of dozen individuals in the world who are qualified to perform this highly skilled task. It requires two years to train a source installer.

E.1 LARGE LWR FUEL FABRICATOR

This facility manufactures nuclear fuel for light water-cooled reactors (LWR's) and employs approximately 2,000 people. The raw material is uranium hexafluoride (UF_6), received in 2 MT containers from the uranium enrichment plants. Enrichment (percent of U-235) varies up to four percent. The finished products are fuel assemblies ready to load into LWR's. Intermediate products consist of UO_2 powder, UO_2 pellets, and fuel rods (strings of pellets clad in zirconium alloy).

The industry is dominated by five large firms. A few small processors manufacture fuel for research reactors or high temperature gas-cooled reactors. In these cases, however, the finished products differ substantially from LWR fuel. Health physics considerations, however, are similar; i.e., the risks are from soluble and insoluble compounds of the uranium isotopes.

The process is similar in most of the large facilities. For some of the producers, the conversion to UO_2 and the processing of the UO_2 into fuel rods are performed at separate sites. Initially, UF_6 from the enrichment plant is converted to UO_2 powder by a chemical ammonium diuranate (ADU) process. The UO_2 powder is processed (e.g., hammermilling, predensification, granulating, blending) to prepare it for subsequent processing. Pressed UO_2 pellets are sintered, ground, and loaded into fuel rods. Fuel rods are assembled into fuel bundles, and the bundles are shipped to various reactor sites. A large number of support activities, such as laboratory analyses, process development, maintenance, and waste treatment are also conducted.

This plant was constructed about 14 years ago. A new section of the facility which recently went into operation has about 50% of the conversion capacity. This section, because of the near total containment, has very low airborne concentrations of uranium.

Potential exists in the plant for both internal exposure from inhalation of uranium compounds and external exposure from the relatively low energy gamma rays emitted by the isotopes of uranium. Most of the potential for internal exposure (inhalation) is at the front end of the plant, where the UF_6 (soluble uranium) is treated chemically to convert it to UO_2 powder. Some potential for inhalation persists as the UO_2 powder (insoluble uranium) is milled, blended, and formed into pellets.

The potential for external exposure is at the sites of storage of large quantities of uranium; i.e., at the UF_6 cylinder dock (fields as high as 3 mr/hr), at the completed fuel assembly area (fields as high as 2 mr/hr), and at storage racks of cans of UO_2 powder (fields as high as 2 mr/hr). Normally, people are present in these areas for only brief periods of time. The highest fields where people normally work is in the fuel bundle assembly area, where dose rates as high as 0.5 mr/hr can be achieved.

External exposure to radiation can be received from sources other than uranium in the plant. There are two X-ray machines for radiographic inspection of fuel rods and/or other assemblies. Another X-ray machine is used for X-ray analytical procedures. Cf-252 neutron sources are used for non-destructive testing of fuel rods.

A systematic procedure has been developed to establish requirements for both external and internal dosimetry of personnel. The decision framework is shown in Exhibit 1. Using this methodology, approximately 1200 personnel are monitored for external exposure (using TLD's).

The philosophy applied to whole-body counting for the detection of insoluble uranium in the lung is described in Exhibit 2. Over a recent 12-month period, an irregular number of employees were counted monthly, 300 were counted quarterly, and 275 were counted annually. In addition, an extensive urinalysis program for the detection of soluble uranium is in place. UF_6 vaporization and hydrolysis operators are required to submit samples at the end of the shift. Maintenance personnel are required to submit daily samples if they performed maintenance in vaporization or hydrolysis. Moreover, special samples are required after UF_6 (UO_2F_2) gas leaks, suspected ingestion of soluble compounds, or in the event of an incident in which it is suspected that soluble materials have been released. Over the last three quarters of 1981, 972 urinalyses were performed.

Air sampling is extensive throughout the plant. There are about 200 sampling points with removable filters that are counted every eight-hour shift. Additionally, a continuous sampling system has been in operation for 2 1/2 years with 33 sampling

EXHIBIT 1

DECISION METHODOLOGY FOR DOSIMETRY AND ACCESS CONTROL

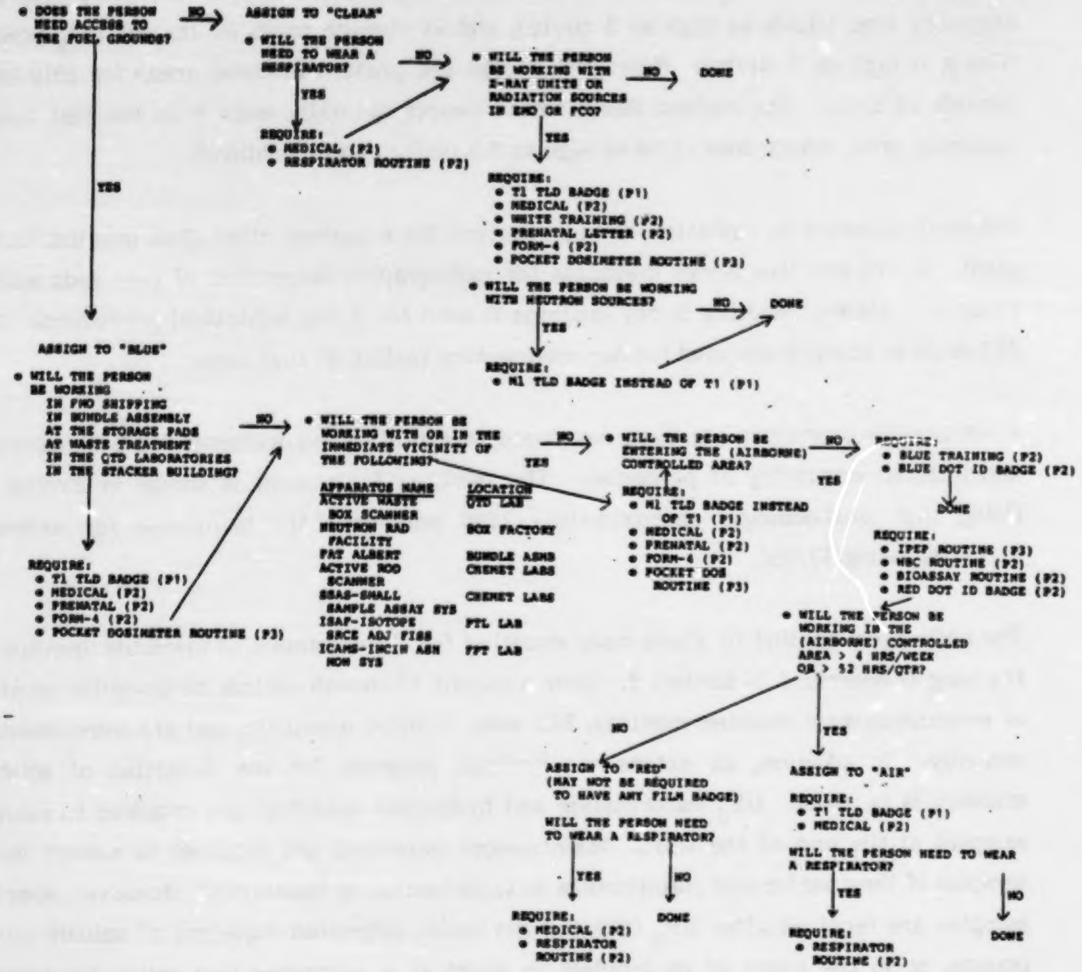

• DOES THE PERSON NEED ACCESS TO THE FUEL GROUNDS?
NO
ASSIGN TO "CLEAR"
• WILL THE PERSON NEED TO WEAR A RESPIRATOR?
NO
YES
REQUIRE:
• MEDICAL (P2)
• RESPIRATOR ROUTINE (P2)
• WILL THE PERSON BE WORKING WITH X-RAY UNITS OR RADIATION SOURCES IN EMO OR FCO?
NO
DONE
YES
REQUIRE:
• T1 TLD BADGE (P1)
• MEDICAL (P2)
• WHITE TRAINING (P2)
• PRENATAL LETTER (P2)
• FORM-4 (P2)
• POCKET DOSIMETER ROUTINE (P3)
• WILL THE PERSON BE WORKING WITH NEUTRON SOURCES?
NO
DONE
YES
REQUIRE:
• M1 TLD BADGE INSTEAD OF T1 (P1)
YES
ASSIGN TO "BLUE"
• WILL THE PERSON BE WORKING
IN FMO SHIPPING
IN BUNDLE ASSEMBLY
AT THE STORAGE PADS
AT WASTE TREATMENT
IN THE QTD LABORATORIES
IN THE STACKER BUILDING?
REQUIRE:
• T1 TLD BADGE (P1)
• MEDICAL (P2)
• PRENATAL (P2)
• FORM-4 (P2)
• POCKET DOSIMETER ROUTINE (P3)
NO
• WILL THE PERSON BE WORKING WITH OR IN THE IMMEDIATE VICINITY OF THE FOLLOWING?
APPARATUS NAME
LOCATION
ACTIVE WASTE BOX SCANNER
QTD LAB
NEUTRON RAD FACILITY
BOX FACTORY
FAT ALBERT
BUNDLE ASMB
ACTIVE ROD SCANNER
CHEMET LABS
SSAS-SMALL SAMPLE ASSAY SYS
CHEMET LABS
ISAF-ISOTOPE SRCE ADJ FISS
PTL LAB
ICAMS-INCIN ASH MON SYS
FPT LAB
NO
YES
REQUIRE:
• M1 TLD BADGE INSTEAD OF T1 (P1)
• MEDICAL (P2)
• PRENATAL (P2)
• FORM-4 (P2)
• POCKET DOS ROUTINE (P3)
• WILL THE PERSON BE ENTERING THE (AIRBORNE) CONTROLLED AREA?
NO
REQUIRE:
• BLUE TRAINING (P2)
• BLUE DOT ID BADGE (P2)
DONE
YES
REQUIRE:
• IPEP ROUTINE (P3)
• WBC ROUTINE (P2)
• BIOASSAY ROUTINE (P2)
• RED DOT ID BADGE (P2)
• WILL THE PERSON BE WORKING IN THE (AIRBORNE) CONTROLLED AREA > 4 HRS/WEEK OR > 52 HRS/QTR?
NO
ASSIGN TO "RED"
(MAY NOT BE REQUIRED TO HAVE ANY FILM BADGE)
WILL THE PERSON NEED TO WEAR A RESPIRATOR?
YES
REQUIRE:
• MEDICAL (P2)
• RESPIRATOR ROUTINE (P2)
NO
DONE
YES
ASSIGN TO "AIR"
REQUIRE:
• T1 TLD BADGE (P1)
• MEDICAL (P2)
WILL THE PERSON NEED TO WEAR A RESPIRATOR?
YES
REQUIRE:
• RESPIRATOR ROUTINE (P2)
NO
DONE

EXHIBIT 2

WHOLEBODY COUNTING POLICIES

Counting Frequency:

ASAP (AS SOON AS POSSIBLE)

1. New hires (if the employee has a previous history of working around radioactive materials) or will be assigned to the controlled area.
2. Terminations (if a weekly POTENTIAL exposure exists >25% or TIA >10% for any quarter).
3. Personnel involved in an incident (assigned daily exposure >400.0E-11 microcuries-hrs/cc).
4. Last WBC >200 micrograms U-235 (if first in a series).

MONTHLY

1. Monthly ASSIGNED airborne exposure >50% (>800 microcuries-hrs/cc).
2. Last WBC >1509 micrograms U-235 until <100 micrograms U-235.

QUARTERLY

1. Quarterly POTENTIAL airborne exposure >100% (>5200.0E-11 microcuries-hrs/cc).
2. Last WBC >MDL.
3. Quarterly ASSIGNED airborne exposure >10% (>520.0E-11 microcuries-hrs/cc).

ANNUALLY

1. Quarterly TIA <25% but >10% (52-130 hrs), or
2. Quarterly ASSIGNED airborne exposure <10% (520.0E-11 microcuries-hrs/cc), and
3. A weekly POTENTIAL exposure >25% (>100.0E-11 microcuries-hrs/cc).

EXHIBIT 2 (Continued)

NOT REQUIRED

1. Quarterly TIA <10% (<52 hours).
2. All weekly POTENTIAL exposures <25% during quarter (<100.OE-11 microcuries-hrs/cc).

POTENTIAL EXPOSURE - No credit taken for respirators.

ASSIGNED EXPOSURE - Credit taken for respirators.

Restriction and Recounting:

WBC RESULT IN μg U-235	ACTION TO BE TAKEN
> 250	RESTRICT and reschedule ASAP.
> 200	Reschedule within 1 to 2 weeks, if second count > 200, RESTRICT and count monthly until result < 100.
> 150	Monthly count until < 100.
> MDL	Schedule for count following quarter
< MDL	No action required.

CONTAMINATION SUSPECTED RESTRICT and reschedule within two (2) weeks.

WBC = Wholebody count

TIA = Time in area

MDL = Minimum Determinable Level

points. The results of the derived airborne concentrations are used to determine compliance with regulations and the need for special bioassays.

The external exposure distribution for 1980 is given in Exhibit 3. Approximately 5% of those monitored, or roughly 50 workers, received whole-body exposures in excess of 0.5 rem. Approximately 0.5% of those monitored, or approximately five workers, were exposed in excess of 1.5 rem. The maximum exposure was approximately 2.5 rem.

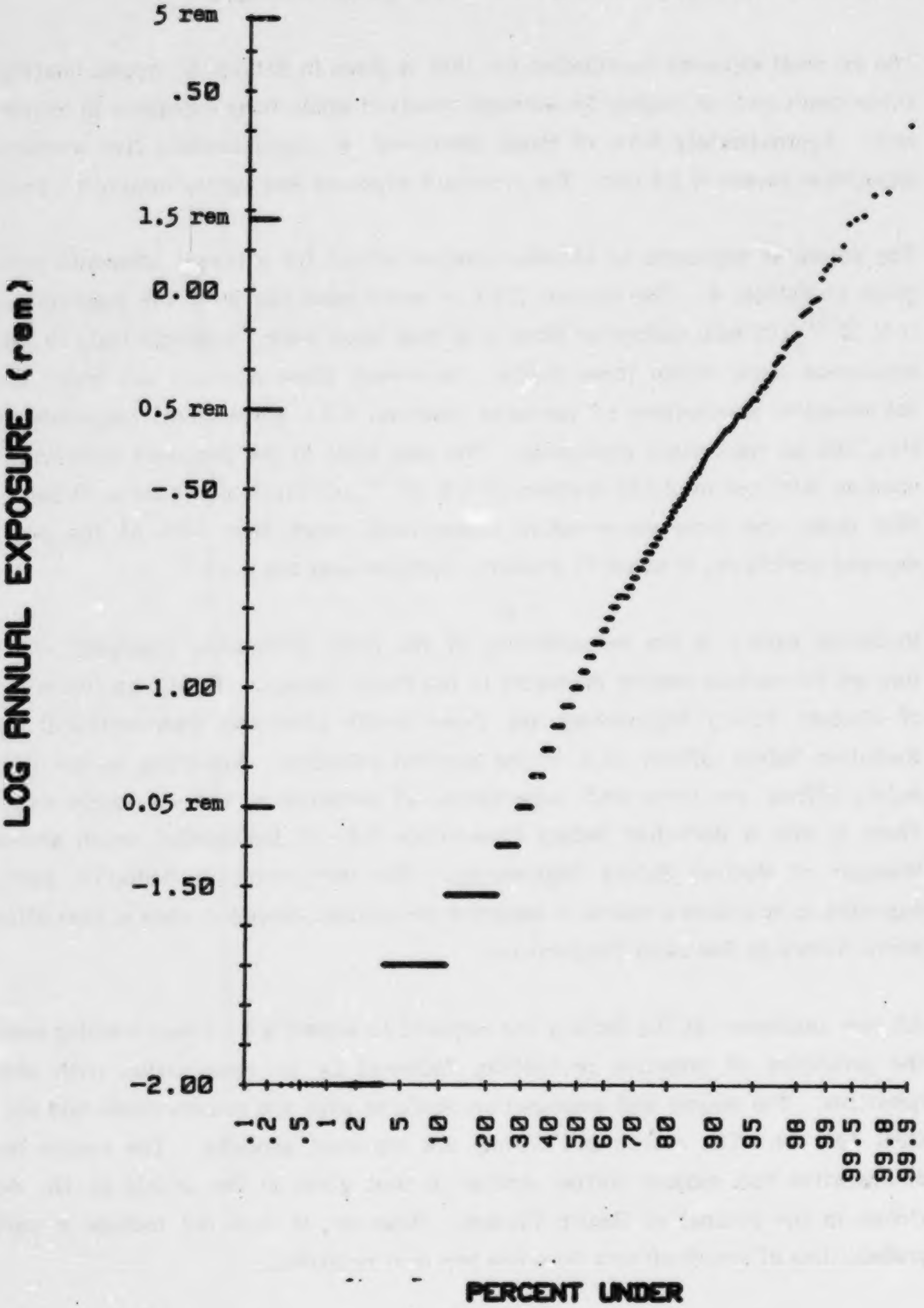
The potential exposures to airborne concentrations for a recent 12-month period are given in Exhibit 4. The current limit is based upon the MPC for insoluble uranium ($1 \times 10^{-10} \mu Ci/ml$), multiplied times a 40 hour work week. Approximately 99.5% of the employees were within these limits. Moreover, these numbers are based upon the conservative assumptions of insoluble uranium, 2.2% enrichment, respirable particle size, and no respiratory protection. The new limit in the proposed guidelines, based upon an MPC for insoluble uranium of $1 \times 10^{-11} \mu Ci/ml$, is also shown. It can be seen that under the same conservative assumptions, more than 60% of the potentially exposed workforce, or about 75 workers, would be over the limit.

Radiation safety is the responsibility of the plant work area managers who report through the various section managers to the Plant Manager. Reporting to the Manager of Nuclear Safety Engineering are three health physicists (non-certified) and the Radiation Safety Officer (B.S. in the physical sciences). Reporting to the Radiation Safety officer are three shift supervisors, 20 technicians, and six hourly employees. There is also a Radiation Safety Committee (10 - 12 individuals) which advises the Manager of Nuclear Safety Engineering. The technicians in Radiation Safety are expected to complete a course in radiation protection principles, such as that offered by North American Rockwell Corporation.

All new employees at the facility are required to attend a 4 - 5 hour training session on the principles of radiation protection, followed by an examination with about 60 questions. The course and examination conform with the requirements laid out in 10 CFR Part 19. The course and testing are repeated annually. The course includes comparative risk subject matter similar to that given in the article by Dr. Bernard Cohen in the Journal of Health Physics. However, it does not include material on probabilities of health effects from low levels of radiation.

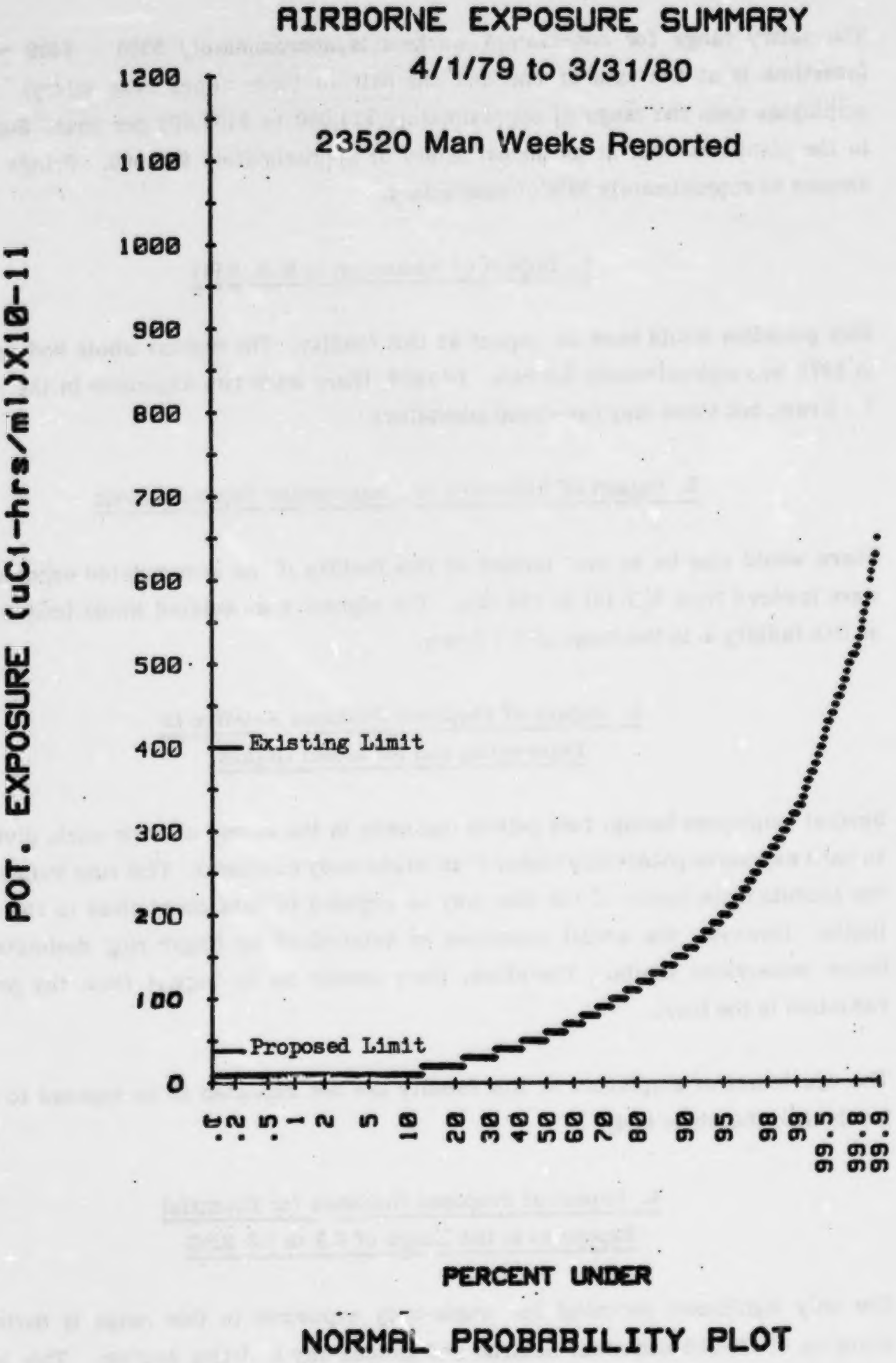
Exhibit 3

>MDL EXTERNAL EXPOSURE 1980



NORMAL PROBABILITY PLOT

Exhibit 4


AIRBORNE EXPOSURE SUMMARY
4/1/79 to 3/31/80
23520 Man Weeks Reported
POT. EXPOSURE (uCi-hrs/ml)X10-11
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Existing Limit
Proposed Limit
.1
.2
.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
PERCENT UNDER
NORMAL PROBABILITY PLOT

The salary range for non-exempt workers is approximately \$300 - \$400 per week (overtime is at the rate of one and one-half to three times base salary). Exempt employees span the range of approximately \$24,000 to \$100,000 per year. Supervisors in the plant peak out at an annual salary of approximately \$45,000. Fringe benefits amount to approximately 28% of base salary.

1. Impact of Reduction in W.B. RPG

This guideline would have no impact at this facility. The highest whole-body exposure in 1980 was approximately 2.5 rem. In 1979, there were two exposures in the range of 2 - 3 rem, but these may have been anomalous.

2. Impact of Reduction in Accumulated Exposure Limit

There would also be no cost impact at this facility if the accumulated exposure limit were lowered from 5(N-18) to 100 rem. The highest accumulated whole-body exposure at this facility is in the range of 2 - 3 rem.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Several employees handle fuel pellets manually in the course of their work, giving rise to hand exposures potentially higher than whole-body exposures. Test runs indicate that the subcutaneous layers of the skin may be exposed to beta doses close to the 75 rem limits. However, the actual exposures as determined by finger ring dosimeters are below measurable limits. Therefore, there should be no impact from the proposed reduction in the limit.

The eye lenses of employees at this facility are not expected to be exposed to higher levels than the whole body.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

The only significant potential for whole-body exposures in this range is during the changing of Cf-252 and other neutron and gamma ray emitting sources. This is done approximately a dozen times annually, and a single operation takes typically one hour. The largest source (2 Ci Cf-252) is changed every two years, and the whole procedure takes approximately eight hours, including pre-planning and equipment setup. During these operations, a technician from the Radiation Safety Office is present and performs continuous monitoring.

The main impact from this proposed guideline would be due to the new internal exposure RPG. Even with respect to existing guidelines, more than 30% of plant personnel are potentially exposed to airborne concentrations in excess of 0.3 RPG (see Exhibit 3). The areas in which one might anticipate airborne concentrations to exceed 30% of the current RPG are the vaporizor, the hydrolyzer, the slab blender, the slugger, the baghouse, the hammermill, the calciner, the pellet press, the grinder, and recycle.

Airborne concentration data over a recent 12-month period indicate that there are approximately 15 hours during the 168 hour week (3 shifts) that one or more of these areas may exhibit airborne concentrations in excess of MPC's. Moreover, the chances of simultaneous high concentrations in two areas is reasonably high. Therefore, two areas may require supervision during such incidents of high airborne concentrations. At present, technicians in the Radiation Safety Office are available to monitor these incidents.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

This facility is currently in full compliance with this proposed guideline. Anyone with the potential for external exposure in excess of 7.5% of the annual RPG is monitored for external exposure. Potential internal exposures are monitored in all production areas by an elaborate system of air monitors. Two health physicists and a staff of technicians maintain records on external fields and airborne concentrations at all production locations, review procedures, and are available to monitor during non-routine operations. Moreover, "radiation protection professionals" are available to assure that exposures are justified and ALARA.

6. Impact of Training Requirements

As discussed earlier, with the exception of the subject area of levels of risk, the current instruction program satisfies the proposed guideline on training. To include quantitative instruction on levels of risk, an additional two hours of training would be required for each of 1200 workers. Instruction is given approximately 20 times annually. Therefore, an additional 40 hours of instructor time (at $30,000 per year) would also be required annually.

7. Impact of the Guidance for Protection of the Unborn

Approximately 25% of the plant personnel are females, most of whom are of child-bearing age. At present, if a woman is known to be pregnant, the management is willing to move her to a zero exposure job if she requests a transfer. If she suspects that she is pregnant and requests a transfer, and it is later determined that she is not pregnant, she will not automatically be able to return to her old job because of plant work rules.

Proposed Alternative b is no different than Alternative a, since there are no jobs in the plant that result in whole-body exposures in excess of 0.2 rem/month.

8. Impact of Internal Exposure and Combined External Exposure Guidance

The current approach at this plant to demonstrate compliance with the existing guidance on internal exposures is to calculate potential exposures to airborne concentrations of uranium from airborne monitoring data plus time and area assignments for personnel. From the calculated potential exposures to airborne concentrations, internal doses are estimated by organ for each individual. These estimated internal doses are checked using the bioassay procedures described earlier. Measured external exposures obtained from personnel dosimetry are routinely added to the estimated internal doses. The software for this elaborate system of airborne concentration tracking and internal dose estimation was developed at a cost of approximately 3 man-years of effort.

As can be seen from Exhibit 3, nearly 70% of the work force is potentially exposed to airborne concentrations in excess of the proposed guideline (MPC of $1x10^{-11}$ μCi/ml). However, these numbers are based upon very conservative assumptions. This facility has been anticipating a change in the regulations since ICRP-26 was published. To

comply with ICRP-30 (Derived Air Concentration for U-235 of 1.6×10^{-11} μCi/ml), the approach to compliance would be the same; namely, calculation of potential concentrations of uranium for each employee. However, the conservative assumptions would have to be relaxed.

The first assumption that would have to be relaxed would be that of totally respirable particle size. Actual particle size distributions at various areas within the plant are well known, but would require verification every couple of years. This might require a man-month each of a professional and a technician. It is expected that using the actual particle sizes would lower calculated potential exposures to respirable uranium by an average of about 30%.

The second relaxed assumption would be that of total insolubility. MPC's for soluble uranium are a factor of 30-40 higher than those of insoluble uranium. The areas of the plant where soluble forms of uranium are handled, primarily at the front end of the process, are readily identified.

The third relaxed assumption would be that of enrichment. At present, a uniform enrichment of 2.6% is assumed in all calculations. Since the actual average enrichment is lower, this assumption is conservative. The use of actual enrichment values in place of this assumption would require plantwide sampling of enrichment. The combined relaxation of the conservative assumptions on solubility and enrichment would lower calculated potential exposures to uranium by a factor of approximately five.

Finally, the amount of time spent by each employee in each area of the plant would have to be estimated more accurately. The current, conservative time and area assignments are based upon 6 1/2 hours per shift for routine controlled area workers. To obtain more accurate time and area assignments, a card key system has been designed (and installed in a few selected areas). This system also contributes to time card and bioassay tracking, as well as security. The cost of the entire system will be approximately $400,000, with an annual operating cost of roughly $50,000. However, only about 25% of these costs should be allocated to better time and area assignments.

All of the above improvements in calculational procedures could be implemented and documented using the existing software with about two man-years of effort. Although it has not been confirmed, it is expected that the effect would be to demonstrate

compliance with the ICRP-30 limits. However, the proposed EPA limits are approximately another 30 - 40 percent lower. At present, it is not clear that these changes will bring calculated potential exposures down to the proposed EPA levels.

It would be possible to use bioassays (i.e., urinalyses), rather than estimated exposures to airborne concentrations to predict organ doses for soluble uranium. In urine, uranium can be detected down to 2.5 μg/l, which corresponds to concentrations of approximately 1/100 of the current MPC. Therefore, this method could be used to determine compliance with the proposed guidelines. It is estimated that the current urinalysis program, which costs approximately \$2000/qtr., would have to be doubled.

With the current state-of-the art, whole-body counting does not have the requisite sensitivity to be used to estimate internal exposures from insoluble uranium. The existing maximum permissible lung burden is 283 μg of U-235, whereas the current sensitivity of the whole-body counter is 75 μg. In order to detect the lung burden corresponding to the proposed guideline, the detectable lung burden would have to be reduced by at least a factor of three. This is not possible at present.

If it were possible to use whole-body counting to estimate the intake of insoluble uranium, the costs of the existing counting programs are estimated to increase by approximately \$120,000 per year. Whole-body counting takes approximately 30 minutes per person. At present, approximately 125 individuals are monitored monthly. To monitor 300 or more individuals, three-shift counter operation would have to be performed. The current operation costs \$80,000 per year.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

As seen in Exhibit 2, only 5 personnel received exposures in excess of 1.5 rem in 1980. These exposures were either derived from changing sources or are possibly anomalous. At any rate, compliance could be achieved with a 1.5 rem limit with little additional effort. Therefore the imposition of this proposed guideline would have no direct cost impact, with the exception of needed closer scrutiny, posting of data restrictions, etc.

E.2 SMALL LWR FUEL FABRICATOR

This company manufactures nuclear fuel for light water-cooled reactors (LWR's). The UF_6 conversion facility receives UF_6 from the enrichment plant in 1.5 MT containers and converts it to UO_2 powder by the chemical ammonium diuranate (ADU) process. This consists of volatilization of UF_6, hydrolysis to UO_2F_2, precipitation with ammonium hydroxide to form ADU, filtration of the ADU, drying and calcining to U_3O_8, reduction to UO_2 in a hydrogen-steam atmosphere, milling, purification, and packaging. Enrichment (percent of U-235) varies up to four percent. The UO_2 facility receives the powder from the UF_6 conversion facility, and processes it by blending, slugging, granulating, and pellet pressing. Pressed UO_2 pellets are sintered, ground, and loaded into fuel rods. Fuel rods are assembled into fuel bundles and the completed bundles are shipped to various reactor sites.

There are approximately 400 employees of the firm involved in LWR fuel fabrication, roughly evenly split between the UF_6 conversion and the UO_2 facilities. However, only about one-third of these would be characterized as radiation workers. These are 80-100 individuals at the UF_6 conversion facility and 30-40 people at the UO_2 facility.

Potential exists at both facilities for internal exposure from inhalation of uranium compounds, as well as external exposure from the relatively low energy gamma rays emitted by the isotopes of uranium. At the UO_2 facility, everyone who is assigned to the plant is monitored with TLD's for external exposure. At the UF_6 facility, only those expected to receive 25 percent of the RPG are monitored currently; in the near future, everyone assigned to the plant will be monitored. The assembly storage area in the UO_2 facility has the highest external fields, approximately 5-6 mr/hr. The annual whole-body exposure distributions for 1980 are given in the Table.

Systematic procedures have been established for internal monitoring, although they are different for the two facilities. At the UO_2 facility, urinalyses are performed quarterly or semi-annually, depending on the number of exposure hours incurred by an individual. Lung counts are also performed quarterly or semi-annually, depending on exposure hours. In the event of a spill, nose smears, fecal samples, and urine samples are also assayed.

WHOLE-BODY EXPOSURE DISTRIBUTIONS FOR THE YEAR 1980

Exposure Range (Rem)	No. of Individuals	
	UF_6 Conversion Facility	UO_2 Facility
No measurable exposure	0	60
Less than 0.10	24	77
0.10 - 0.25	6	33
0.25 - 0.50	0	27
0.50 - 0.75	0	1
0.75 - 1.0	0	1
1.0 - 2.0	0	4
2.0 - 5.0	0	0
> 5.0	0	0
TOTAL	30	203

At the UF_6 facility, frequency of urinalysis is a function of an individual's job. For people working in the UF_6 vaporization area, urinalyses are performed six times annually; for all others, the frequency is lower. The frequency of lung counting, which ranges from once to four times annually, is dependent on an individual's historical body burden. A lung count plus a fecal sample are also taken in the event of a spill.

Compliance with the regulations is demonstrated using measured air concentrations in conjunction with time and area assignments. At the UO_2 facility, 25 air samplers are monitored once a shift. At the UF_6 facility, 80 stations, which are sampled once a day, are supplemented by a continuous alarmed air monitor. Lapel samplers are also worn by selected individuals at both facilities. These samplers are used primarily for purposes of verification of exposure.

In 1980, the average annual internal exposure at the UO_2 facility, expressed in units of area concentration hours, was 9.15×10^{-9} μ Ci-hrs/ml, or 4.4 percent of the limit.* (This varied by less than 25 percent over the years 1977 through 1980). In 1980, approximately 12 percent of the personnel exceeded ten percent of the average annual limit. This number is low because personnel are stricted from radiation work whenever they exceed 20 MPC-hrs. in any single week.

At the UF_6 conversion facility, the average area concentration hours were 10.2% of the limit.* A very rough estimate of the areas that exceed ten percent of the average annual limit is 50 percent.

At the UF_6 conversion facility, the Radiation Safety Officer, who reports to the plant manager, has a Master's degree in health physics. He has a staff of six personnel, one of whom is also a health physicist. Neither of the health physicists are certified. The Health and Safety Supervisor, who also reports to the Radiation Safety Officer, has 20 years of experience, and is considered to have the background and experience equivalent to that of a health physicist.

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* These numbers take credit for respiratory protection.

The Radiation Safety Officer at the UO_2 facility also reports to the plant manager. Although he has an academic background in physics and business, he has two health physicists (neither certified) on his staff. Additionally, a licensing administrator, a health and safety foreman, and five technicians assist in health and safety activities.

Verbal instruction in radiation protection principles is provided individually to new hires at both facilities. This instruction ranges from one to two hours, depending on the nature of the job. Also, various handouts on respiratory protection and physics are provided. At present, only fertile females are provided instruction on levels of risk. However, a canned presentation is being prepared to provide everyone with information on the risks associated with exposure to radiation.

1. Impact of Reduction in W.B. RPG

There would be no impact from a reduction in the RPG to 5 rem/yr. The highest external exposure in 1980 was 1.5 rem.

2. Impact of Reduction in Accumulated Exposure Limit

There would also be no cost impact at this facility if the accumulated exposure limit were lowered from 5(N-18) to 100 rem.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

The hands of several technicians are exposed in the course of fuel pellet handling. However, the high exposures involve beta radiation, which does not penetrate to the subcutaneous layer of the skin. Therefore, average annual exposure to the entire hand is relatively low, estimated to be a maximum of 2 rem.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

There were no external exposures in excess of 1.5 rem in the past two years. Moreover, there were no internal exposures in excess of 0.3 RPG, since this facility has been operating under the NRC ALARA goal which is 25 percent of the RPG. The total exposure, external plus internal, exceeded 1.5 rem for a few individuals, but the current NRC regulations do not require the summation of these exposures.

If the proposed new guidelines on internal exposures, in particular the new Derived Air Concentrations, were imposed, it would be difficult to maintain combined exposures below 30 percent of the RPG. (The difficulty in meeting the new RPG is discussed later in this case study.) However, the 30 percent goal would be factored into the planning to meet the new RPG, since it is anticipated that NRC would still insist upon a 25 percent ALARA goal.

Each facility maintains a staff of at least two health physicists and several supporting radiologic technicians. Therefore, spills that would result in area exposure rates significantly contributing to annual internal dose exceeding 0.3 RPG could easily be monitored and supervised by radiation protection professionals.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The firm is currently in full compliance with this guideline, and would have no difficulty in complying under a reduced RPG. Potential internal exposures are monitored at both facilities by extensive arrays of air monitors. Two health physicists and a staff of technicians at each facility maintain records of external fields and airborne concentrations, review procedures, and are available to monitor during non-routine operations. Moreover, radiation protection professionals are available to assure that exposures are justified and ALARA.

6. Impact of Training Requirements

The current program, with the possible exception of instruction on levels of risk, satisfies the proposed guideline on training. To include quantitative instruction on levels of risk, an additional hour of time would be required annually for each of 200 workers. Also, an additional 10 hours of instructor time would be required annually.

7. Impact of the Guideline for Protection of the Unborn

Approximately one percent of the plant radiation workers at both facilities are female, most of whom are of child-bearing age. Presently, the management conforms to

Alternative a; namely, if a woman states that she is pregnant, she will be moved to a zero exposure job if she requests a transfer. Since there are no jobs in the plant resulting in exposures to the unborn of 0.2 rem/month, Alternative b is not relevant at this plant.

8. Impact of Internal Exposure and Combined External Exposure Guidance

The aspect of the proposed guidelines that would cause a severe impact at these facilities is the reduction by an order of magnitude in the Derived Air Concentrations (DAC's) for uranium. This comes about largely from the application of the new models. At present, roughly 50 percent of the personnel at the UF_6 conversion facility are exposed annually to concentrations in excess of the proposed DAC, and approximately 12 percent of the personnel at the UO_2 facility exceed the limit. (The impact was compared to a reduction in the speed limit for trucks from 55 to 5 miles per hour.)

The order of magnitude reduction would require glove box containment for nearly all operations at both facilities. In fact, the proposed new insoluble uranium DAC (1 x $10^{-11} \mu$Ci/ml) is lower than the existing insoluble plutonium MPC (4 x $10^{-11} \mu$Ci/ml), and total containment is standard operating procedure with respect to plutonium. (Although, the amount of mass corresponding to comparable levels of activity is 10^4 - 10^5 lower in the case of plutonium.) Moreover, since the NRC has established an ALARA limit at 25 percent of MPC, it is believed that a comparable ALARA reduction below the proposed DAC would continue to be imposed.

Currently, the operations in both facilities that generate high airborne concentrations are enclosed in hoods. These include the hammer mill feed station, the blender loading port, the granulator, the pellet press, the furnace loading ports, the grinders, etc. If the reduced DAC were to be imposed, all of these operations would be sealed in glove boxes.

Rough cost estimates were made by engineering designers at both facilities of the capital costs associated with conversion of the existing hoods to glove boxes. For the combined UF_6/UO_2 facilities, the estimate in 1982 dollars is \$2.4 million for containment, \$2.4 million for process modifications, \$3.1 million for ventilation and \$1.9

million for engineering and construction supervision. Thus, the total cost at both facilities is estimated to be $9.8 million.

In addition to required plant modifications, there would be increases in operating costs from several sources. These include decreased efficiency and throughput, and increased costs of solid waste management (i.e., more wastes from the inability to reuse boxes for interim storage of pellets) and health physics (i.e., more counting man-hours.) A rough estimate of these costs is 1.2 million dollars per year.

Improved calculations of exposure (i.e., relaxation of conservative assumptions) is not considered to be a desirable approach for compliance with the proposed DAC's, nor is it believed that compliance could be achieved in this way. In fact, it is policy in this firm to achieve compliance through engineering modifications, rather than administrative fixes.

On the other hand, the potential for compliance through modifications in calculational techniques has not been thoroughly researched. Data generated by another firm indicate that approximately 40 percent of the airborne particles, on the average, are non-respirable. However, it would take more than a year to generate data specific to this firm. Solubility data are even more difficult to obtain, and less reproducible. It is not clear that either solubility or particle size are controllable variables, or that the NRC inspection and enforcement personnel would accept these data for purposes of compliance.

Assignments of time in specific areas for all personnel is difficult, if not impossible to accomplish. Besides, it felt to be a "game," rather than a rigorous demonstration of compliance.

Even if all of these refinements were included in the system, it is felt that compliance with the proposed DAC could not be achieved, and, for sure, an ALARA limit at 25 percent of the DAC would be impossible to meet.

Other aspects of the proposed internal exposure guidelines — weighted organ doses, additive internal and external doses, etc. — are only bookkeeping problems and would involve minimal costs.

9. Impact of the Reduction of the W.B. RPG to 1.5 rem/yr.

Because external exposures rarely exceed 1.5 rem/yr, the imposition of this guideline would have no cost impact.

F. WELL LOGGER

Well logging is a technique to determine the properties of subsurface rock. Applied in the exploration for several minerals, most of the service is sold to the oil and gas exploration industry. The properties of rock that are of interest include porosity, permeability, fluid content, and geometrical configuration of the reservoir. Some of these properties can be obtained by coring, whereas others, such as fluid content, cannot. In well logging, various instruments are lowered into the shaft, to depths up to 35,000 feet, and non-destructive measurements are made over the entire length of the shaft. These measurements include resistivity, electron density, spontaneous potential, sonic attenuation, sonic travel time, and hydrogen concentration.

Two of these measurements involve the use of radiation. To measure electron density, a gamma ray source, usually Cs-137 (~1/2 to 2 Ci) is used. For the measurement of hydrogen concentration, neutron sources are used. The neutron sources are generally Am-Be (1 to 20 Ci) or Pu-Be (smaller companies may still use Ra-Be), although in approximately 5% of the measurements an electronic source (electron bombardment of tritium) is used in the pulsed mode. The radioisotope sources, of which the case study firm possesses approximately 3,000, are doubly encapsulated in stainless steel and tested to 1500°F and 25,000 psi. They are fabricated by outside vendors and assembled into the source holder manually upon receipt. The source holder also provides an order of magnitude collimation along its axis. This collimation, provided for measurement purposes, adds a measure of safety for handling of the source. The assembled source is loaded into a lead (or poly, as appropriate) DOT-approved shield (less than 200 mr/hr on the surface) for transportation to the site.

This well logger is one of five large firms that perform about 80% of these services nationwide. The remaining 20% is performed by approximately 200 - 300 small operations. These small "mom and pop" operations, however, must each have an investment in equipment in excess of $500,000.

Total employment in the industry is estimated to be approximately 25,000, and this firm employs its proportionate share. The heart of the operation consists of the field teams, each typically comprised of three members — two operators and a field engineer. In this particular company there are 700 such teams in this firm engaged in roughly 400 jobs on any given day. The operators load the equipment onto the truck and drive the truck to the site. They are met at the site by the field engineer, who supervises all activities at the site.

At the site, the truck is unloaded, the equipment is calibrated, the tools are loaded into the hole, and measurements are made (continuously as the instruments are moved at a uniform rate down the hole). For a typical well, the measurements take from three to 50 hours (12 hours on the average). The only time in which the crew is exposed at the site is while the source is removed from the transportation package and slipped into the logging tool. This generally takes from 30 to 90 seconds. The crew is paid on an incentive basis, thus it is advantageous to complete the job in as short a period of time as possible. Additionally, the work is tedious and must be completed by the same crew (jobs have taken as long as six days).

Operators, who range in age from 21 to 30, generally have a high school education and, depending on how hard they work, typically can earn between $20,000 and $30,000 per year. Field engineers, generally in the same age bracket, can earn as much as $45,000 per year, and must have a degree in engineering or a bachelor's degree in one of the hard sciences (i.e., physics, geology, etc.). Travel requirements and odd hours contribute to a high turnover rate for both operators and field engineers.

Approximately 3,000 employees are monitored, most of whom are operators and field engineers. Additionally, clerks, truck maintenance men, and technicians are monitored. The highest exposures are received by the handful of technicians who load the sources into the source holders upon receipt from the fabricator. They may receive as much as 0.6 rem per quarter. Exposures in the field are considerably lower; the anticipated doses are roughly 0.2 rem/qtr. The only other potential for exposure is during monthly calibration of the sources at the field facilities.

The distribution of exposures for calendar year 1979 is given in the attached Table. TLD's, rather than film, are used for monitoring exposures. These are found to hold up better under the conditions in the field, and are not prone to fading over the three-month period between readings. The cost of the outside dosimetry service which provides the TLD's is $18/yr (quarterly readings). The measured doses for neutrons are felt to be accurate to within ± 200%.

WHOLE BODY EXPOSURE
DISTRIBUTION FOR THE YEAR
1979

Well Logging Firm

Annual Whole Body Dose Ranges * (Rems)	Number of Individuals in Each Range
No Measurable Exposure	401
Measurable Exposure Less Than 0.100	768
0.100 -- 0.250	759
0.250 -- 0.500	733
0.500 -- 0.750	348
0.750 -- 1.000	214
1.000 -- 2.000	277
2.000 -- 3.000	34
3.000 -- 4.000	1
4.000 -- 5.000	2
5.000 -- 6.000	0
6.000 -- 7.000	0
7.000 -- 8.000	0
8.000 -- 9.000	0
9.000 -- 10.000	0
10.000 -- 11.000	0
11.000 -- 12.000	0
> 12.000	0
Total number of individuals reported	3537

The exposures of clerks and maintenance personnel are at the very low end of the distribution given in the attached Table. The 4 - 5 technicians who load the sources are at the high end. The operators and field engineers are equally exposed. There is no correlation between logging time and magnitude of exposure. Once the source is in the hole, there is essentially no exposure to personnel. Even if the source becomes lost in the hole, a not infrequent occurrence, no exposure is encountered during the "fishing" operation, because the source is at depth. There may be higher exposures for shallow holes, since the source goes in and out more often. Generally, wells in the midwest and east are shallower than those in the Gulf states. Depths are variable in the West.

The safety director for the firm is also Radiation Safety Officer and Chairman of the Radiation Safety Committee. The Safety Office, with responsibilities considerably broader than radiation, is comprised of two professionals at the corporate level, one professional for manufacturing and one individual at each of four unit offices. The unit offices coordinate activities at a total of 100 field facilities.

Safety personnel are generally drawn from the ranks of the field engineers. Although there are no certified health physicists, the Radiation Safety Officer has 30 years of field experience and a bachelor's degree in engineering. He additionally attended a 10 week course on radiation protection principles at Oak Ridge National Laboratory, and attended some special courses at the University.

Each of the field engineers has approximately six months of training, ten weeks of which are at special learning centers. The instruction at the learning centers includes radiation protection principles. Operators do not receive formal instruction, but are provided a 20 page booklet on radiation protection. Monthly safety meetings are held at the districts. All available personnel (not on jobs) attend. Twice a year, these safety meetings are devoted to radiation safety.

1. Impact of Reduction in W.B. RPG

There would be no anticipated cost to the firm if the W.B. RPG were reduced from 3 rem/qtr. to 5 rem/yr. There have been no recorded exposures in excess of 5 rem/yr in recent memory and it is not felt that the additional flexibility provided by a higher permissible annual limit would be necessary. In fact, it was felt that the substitution of the 3 rem/qtr. limit with an annual limit of 5 rem, all of which could possibly be received in one quarter, might provide an added degree of flexibility.

2. Impact of Reduction in Accumulated Exposure Limit

The reduction of the accumulated exposure limit to 100 rem is not anticipated to involve a cost impact to this firm. The highest cumulative exposure is currently 11 rem. The turnover rate of operators and field engineers is relatively high. If a field engineer should remain with the company as long as 20 years, he would no doubt be promoted to a management job somewhere along the line, thus eliminating any further exposure.

The opinion was expressed that although cumulative exposure records are always requested from previous employers, a response is seldom received. Apparently the military is particularly unreliable. Colleges and universities are generally reliable.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

There is no reason to believe that the extremities or the eyes receive higher exposures than the whole body. This is also true for the technicians who load the sources into the holder. Accordingly, no extremity monitoring is performed.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Approximately 9% of the monitored workers received exposures in excess of 1.0 rem (the number in excess of 1.5 rem is not readily available) in 1979. Moreover, since most of the exposures to non-field personnel are less than 0.1 rem/yr, the percentage of field personnel who received exposures in excess of 1.0 rem is estimated to be roughly 13%. Therefore, it might be "anticipated" that exposure to field personnel would exceed 1.5 rem in any one-year period.

If each task were to be considered to "significantly" contribute to the annual exposure, a supervisor would have to be present before and during the operation in which the source is removed from the package and slipped onto the logging tool. Since the field teams are geographically dispersed, and typically 400 jobs are ongoing at any one time, the implication of this proposed guideline is that each of the field teams would require the presence of a supervisor. Moreover, since the jobs are not constrained to single shift operations, as many as 700 supervisors could be required.

Although the field engineers are well-trained, including instruction in radiation protection, they are clearly not equivalent in background or training to health physicists.

Additionally, a health physicist would have to be present at the loading of the sources into the holders at headquarters, and during the monthly source calibration at the district offices.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

In addition to the personnel monitoring requirement, which is currently being satisfied by this firm, this guideline requires the availability of a "radiation protection professional" to assure that exposures are justified and ALARA. The activities in the field involving the use of radiation sources are relatively routine, and are prescribed by procedures drafted by the Radiation Safety Officer. Any time procedures or equipment are changed, the Radiation Safety Officer at Headquarters becomes involved. Therefore, the activities prescribed by this guideline are currently being carried out. However, there remains the question whether the Radiation Safety Officer, whose credentials are described above, is equivalent in background and experience to a "radiation protection professional."

If the Radiation Safety Officer does not qualify, an outside consultant with the appropriate credentials would have to be retained to satisfy this guideline. This might be difficult, since there are believed to be only three certified health physicists in the geographical location of this firm's headquarters.

6. Impact of Training Requirements

As discussed earlier, the field engineers do attend formal training course in radiation protection principles. Although they do not currently receive instruction on quantitative levels of risk, this is being added to the curriculum at a cost of $10,000. The material given in NRC Regulatory Guide 8.29 will be provided in a new booklet.

At present, no formal instruction is provided to the operators in radiation protection principles. If a one-hour period of instruction were to be provided to each new employee, 1200 person-hours of new-employee time would be involved annually. As discussed earlier, the range of salaries for operators and field engineers is $20,000 to

$40,000 per year. Moreover, because of the diffuse locations in the field (approximately 100 field facilities), instruction would be required more or less on a one-on-one basis (approximately one new employee per month at each field location). Therefore, the instruction at this firm would occupy roughly 1200 hours of district manager time. A typical district manager's salary is approximately $50,000 per year. An alternative would be to hold classes monthly at headquarters, involving an additional cost of approximately $62,000 in new employee time and $150,000 in travel and expenses per year.

7. Impact of the Guidance for Protection of the Unborn

There are presently 25 female operators and 20 female field engineers, nearly all of whom are of child-bearing age. The firm is under considerable EEO pressure to increase these numbers. The firm's radiation protection booklet includes a verbatim description of the NRC's prenatal requirements. New female employees are urged to read this section and to discuss it with their district managers. Although the firm currently operates under alternative a, there are no other jobs available if a female voluntarily removes herself from a field assignment. Several females have announced to management that they are pregnant and that they desire to remain on the job. In these cases, the managers emphasize the need to strictly follow procedures, in which case exposures in excess of 0.5 rem to the unborn are highly unlikely. Moreover, pregnant females are not likely to work more than six months, because field work entails the lifting of heavy machinery.

If procedures are strictly followed in the field, it is also unlikely that exposures in excess of 0.2 rem/month would be received. Therefore, females who wish to limit their exposures because they suspect that they are pregnant or they are trying to get pregnant, can easily do so by being very careful. They are not, however, given the option of a non-field job.

If Alternative c were in force, fertile females would just not be hired for the field. This would play havoc with the firm's EEO objectives. It would mean that they would have to meet their quotas by placing women in non-field jobs, of which there are less. Moreover, the non-field jobs that satisfy EEO objectives are accounting, legal, and machinists, for which there are few qualified women. Because there are very few females in field jobs presently, the costs of Alternative c would be minimal. It would involve discharging the women presently in the field, and increasing the annual recruiting effort by roughly 4%. This would involve a one-time recruiting and training cost.

8. Impact of Internal Exposure and Combined External Exposure Guidance

Currently there is only one use of unsealed sources by the firm, which involves the only potential for internal exposures. This is the use of I-131 as a tracer for investigating the migration of fluids in wells. Approximately 10 mCi (the NRC limit is 50 mCi) of iodine salt in an alkaline buffered solution is injected directly into the well. Other companies perform this procedure more frequently than this firm. According to an NRC Regulatory Guide, bioassays are not required as long as the amount of radioactivity is less than 50 mCi. Therefore, the firm does not perform bioassays on the employees involved with this procedure. Since monitoring is not required, and since this is the only radionuclide with potential for internal exposures, no cost impact is anticipated from the proposed internal exposure guideline.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

As discussed earlier, only 8% of the total work force, or possibly 14% of the field staff, receive exposures in excess of 1.0 rem/yr. (the fraction over 1.5 rem is not readily available). If procedures were followed, exposures could be kept below 1.5 rem/yr. In fact, experience has shown that a maximum exposure of 0.3 rem per quarter is expected if procedures are followed. However, the opinion was also expressed that "people are not perfect" and that it is virtually impossible to get 3,000 people involved in 200,000 operations per year to follow procedures. One possibility would be to have a multiplicity of inspectors, who would drop in occasionally to monitor the field crews. To monitor one-third of the 400 operations daily would require approximately 100 inspectors. However, the purpose could probably be accomplished with a lower frequency of inspection, resulting in fewer inspectors.

Another possibility is to lower the source strength. However, the current well traverse speed is dictated by the source strength (counting statistics limited), so that a factor of two reduction in source strength would increase the logging time (when using the sources) by a factor of two. Since radioactive sources are used approximately 60% of the on-site time, this reduction in source strength would, in effect, increase the well-logging time by 60%. Therefore, to get the same amount of work done, roughly 60% more people would be required. More efficient detectors are not the answer, since the existing detectors are as efficient as the current technology permits.

G. PRIVATE DENTAL FACILITY

This large dental facility is located in a major northeastern urban center. The facility has been operating for 15 years and it is typical of a large number of multi-chair full service dental operations that are being developed across the country. This trend is in part a result of new opportunities for dentists to advertise their services and increase volume to achieve economies of scale in operations. This facility has a staff of 11 dentists covering all major dental subfields. Six dentists are on duty at any one time. The facility operates daily from 9:00 am to 7:30 pm and on Saturday from 9:00 am to 12:00 am. An average weekday patient load is 175 patients of which 25 are first-visit patients. The Saturday patient load is about 25, all of which are first-visit patients.

The facility advertises in large and small area newspapers, as well as conducting direct mail advertising compaigns. Approximately 20 percent of their patient volume is developed through these efforts, with the bulk of their patient load coming from their support of dental plans for several major unions. In some cases, the union may have a prearranged self-insurance plan with the facility or the plan may be run by a major insurance firm. Most billing is made directly to the union or insurance carrier with any minimum deductible fees for union members or their families waived by the facility.

The two floor operation is divided into reception, operatorium, laboratory and administrative areas. The operatorium is subdivided into about 15 cubicles, 11 of which are equipped with a standard wall-attached, heavy-duty dental X-ray machine. One room is equipped with a Panorex X-ray machine, designed to develop exposures of the entire mouth in one sitting. The Panorex is a new machine; all the others are over 20 years old. The machines are maintained by a technician who visits the facility periodically (no set schedule) or upon request. All of the exterior walls, interior separator walls and doors are lead-lined.

The facility employs 30 to 35 individuals, of which 17 to 22 can be identified as radiation workers. These include 11 dentists (all male) and nine dental technicians (all female) and may include the administrator, who spends some time in the operatorium and is badged. All dentists, dental assistants and the administrator are badged, for a total of 17 to 22 badges that are read monthly. Badges are worn at the collar and are required for all personnel in these categories. Monthly reports, as shown by the attached Table, are reviewed by the administrator or the chief dental assistant and any measurable exposure is investigated. All measurable exposures observed in this facility have been for dental assistants and have been small (21 mrem is the highest one-month exposure recorded). All recorded measurable exposures have been traced to non-personnel exposures, such as leaving a badge in a cubicle on a day when the employee is not working.

Standard procedures and training for new personnel are the responsibility of the chief dental assistant. All X-rays are taken with only the patient remaining in a lead-enclosed cubicle and the exposure is triggered from a switch in the hallway. All traffic in the hallway is stopped during exposure. Each new patient receives a Panorex X-ray on the first visit; regular patients receive one about every 24 months, so that about 325 of these exposures are taken per week. In addition, each patient may receive three or four standard X-rays during the course of a treatment (average three to four visits per treatment) or about 175 exposures per week. Procedures are explained to new dental assistants in a one-hour briefing that covers all aspects of the position by an on-the-job training period supervised by the chief dental assistant.

As the Table shows, there has been almost no record of measurable exposure at this facility. The two non-zero readings were both identified as badges left in a cubicle for an entire day. Therefore, there is no impact from the proposed guidance on this facility. This facility may not be typical of exposures due to the lead-lined walls. It was suggested that the capital investment made in this facility might not have been made if the operator had not owned the entire building and thus, did not risk losing a lease. It was also noted that the insurance companies require the submittal of before and after X-ray records to prove that billed-for work was completed. In some cases, the insurance companies also utilize these X-rays to evaluate the complexity and thus, the fee for treatment.

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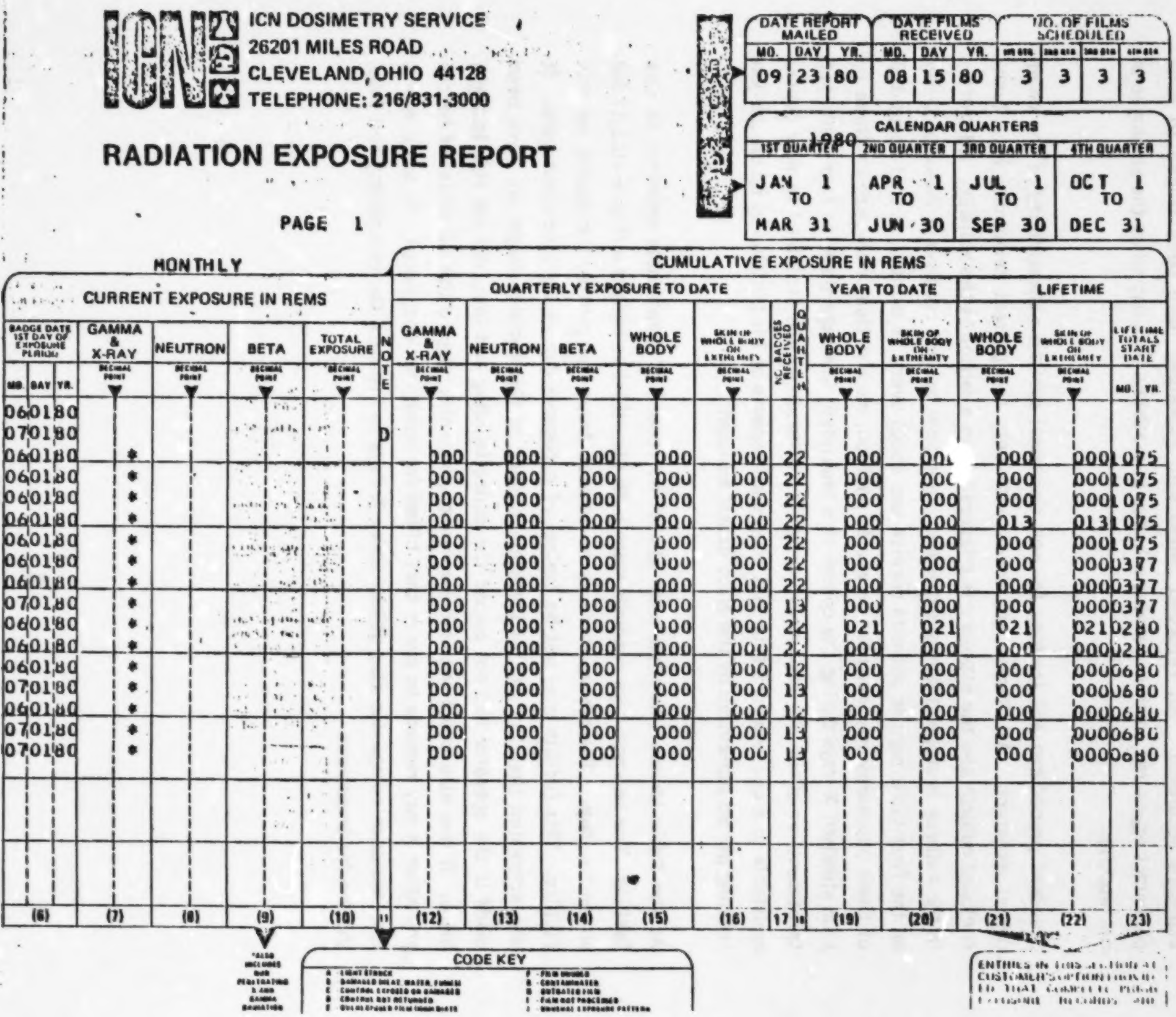
RADIATION EXPOSURE REPORT



ICN DOSIMETRY SERVICE
26201 MILES ROAD
CLEVELAND, OHIO 44128
TELEPHONE: 216/831-3000

RADIATION EXPOSURE REPORT

PAGE 1

DATE REPORT MAILED			DATE FILMS RECEIVED			NO. OF FILMS SCHEDULED			
MO.	DAY	YR.	MO.	DAY	YR.				
09	23	80	08	15	80	3	3	3	3

CALENDAR QUARTERS 1980

1ST QUARTER	2ND QUARTER	3RD QUARTER	4TH QUARTER
JAN 1 TO MAR 31	APR 1 TO JUN 30	JUL 1 TO SEP 30	OCT 1 TO DEC 31

MONTHLY

CURRENT EXPOSURE IN REMS								CUMULATIVE EXPOSURE IN REMS: QUARTERLY EXPOSURE TO DATE							YEAR TO DATE		LIFETIME			
BADGE DATE 1ST DAY OF EXPOSURE PERIOD			GAMMA & X-RAY	NEUTRON	BETA	TOTAL EXPOSURE	NOTE	GAMMA & X-RAY	NEUTRON	BETA	WHOLE BODY	SKIN OF WHOLE BODY OR EXTREMITY	NC BADGES RECEIVED	QUARTER	WHOLE BODY	SKIN OF WHOLE BODY OR EXTREMITY	WHOLE BODY	SKIN OF WHOLE BODY OR EXTREMITY	LIFETIME TOTALS START DATE	
MO.	DAY	YR.	DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼		DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼			DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼	DECIMAL POINT ▼	MO.	YR.
06	01	80																		
07	01	80					D													
06	01	80	*					000	000	000	000	000	2	2	000	00[illegible]	000	000	10	75
06	01	80	*					000	000	000	000	000	2	2	000	00[illegible]	000	000	10	75
06	01	80	*					000	000	000	000	000	2	2	000	000	000	000	10	75
06	01	80	*					000	000	000	000	000	2	2	000	000	013	013	10	75
06	01	80	*					000	000	000	000	000	2	2	000	000	000	000	10	75
06	01	80	*					000	000	000	000	000	2	2	000	000	000	000	03	77
06	01	80	*					000	000	000	000	000	2	2	000	000	000	000	03	77
07	01	80	*					000	000	000	000	000	1	3	000	000	000	000	03	77
06	01	80	*					000	000	000	000	000	2	2	021	021	021	021	02	80
06	01	80	*					000	000	000	000	000	2	[illegible]	000	000	000	000	02	80
06	01	80	*					000	000	000	000	000	1	2	000	000	000	000	06	80
07	01	80	*					000	000	000	000	000	1	3	000	000	000	000	06	80
06	01	80	*					000	000	000	000	000	1	[illegible]	000	000	000	000	06	80
07	01	80	*					000	000	000	000	000	1	3	000	000	000	000	06	80
07	01	80	*					000	000	000	000	000	1	3	000	000	000	000	06	80
(6)			(7)	(8)	(9)	(10)	11	(12)	(13)	(14)	(15)	(16)	17	18	(19)	(20)	(21)	(22)	(23)	

*ALSO INCLUDES [illegible] PENETRATING X AND GAMMA RADIATION

CODE KEY

- A - LIGHT STRUCK
- B - DAMAGED (HEAT, WATER, FUMES)
- C - CONTROL EXPOSED OR DAMAGED
- D - CONTROL NOT RETURNED
- E - [illegible]
- F - [illegible]
- G - CONTAMINATED
- H - [illegible]
- I - FILM NOT PROCESSED
- J - UNUSUAL EXPOSURE PATTERN

ENTRIES IN THIS SECTION AT CUSTOMER'S OPTION [illegible] TO THAT [illegible] EXPOSURE RECORDS [illegible]

H.1 ROCKY FLATS PLANT

The Rocky Flats Plant, operated under contract with the U.S. Department of Energy by Rockwell International, manufactures nuclear components for nuclear weapons. The plant is approximately 30-years old. Weapons-grade plutonium (approximately 93% Pu-239) is the primary radioactive material handled at the facility. Depleted uranium is also handled in significantly large quantities. On occasion, uranium-233 and uranium-235, are handled in relatively small quantities. Additionally, the facility contains a few sources of cesium-137 and cobalt-60, used for radiographic purposes. There are also a few radiographic x-ray machines at the plant.

The input stream consists of both fresh plutonium direct from the production reactors at the Savannah River Laboratory and "old" plutonium from retired nuclear weapons. The "old" plutonium contains americium-241, which grows in as a decay product of plutonium-241 and must be separated from the plutonium. This separation operation, together with scrap recovery from other operations at the facility, is performed in a wet chemical process, which dissolves the material in an acid solution and converts the plutonium to the oxide state. The plutonium oxide is fluorinated to PuF_4, which in turn is reduced to plutonium metal with calcium.

The manufacturing operations at the plant are performed on the pure plutonium metal. These operations include melting, casting, pouring, rolling, shearing, shaping, pressing, welding, drilling, and machining. Thus, virtually all conventional metal-working operations are conducted at the facility. However, because of the radiotoxicity of plutonium, all of these operations are performed in glove boxes.

The plant employs approximately 5,000. Of these, there are roughly 800 "radiation workers," defined as those employees who actually work with plutonium in glove boxes. Another 800 "incidental radiation workers" are potentially exposed to radiation in their work (i.e., craftsmen), but do not deal with plutonium in a hands-on fashion. Approximately 350 employees in health, safety, and environment are also potentially exposed to radiation. Finally, approximately 1,000 additional employees in research and development and production support might receive occasional exposures.

All of the plant employees are monitored for radiation exposure. External monitoring is performed using TLD's which are sensitive to both neutrons and gamma rays. The TLD's are currently read by hand; however, a new Panasonic unit will soon automate the process. For the 800 radiation workers, the TLD's are read bi-weekly. Monthly readings are taken for the incidental radiation workers and the support personnel potentially exposed. All other TLD's are read quarterly. About half of the radiation workers additionally wear ring badges to monitor hand exposures.

The annual external exposure distributions for 1981 and 1982 are given in the Table. The highest external W.B. exposure in 1982 was less than 2 rem. The average measurable exposure was less than 500 mrem. Most of the external dose is received in chemical processing operations. Roughly 50% of the dose is from neutrons, which are largely derived from the (α, n) reaction in fluorine (plutonium tetrafluoride is an intermediate product in the chemical process).

EXTERNAL WHOLE-BODY EXPOSURE DISTRIBUTIONS FOR 1981 AND 1983

Exposure Range (rem)	Number of Individuals	
	1981	1982
0 - 1	4281	5029
1 - 2	63	109
2 - 3	1	0
> 3	0	0

Internal exposures are monitored with an extensive bioassay program. Lung counts by the plant's four whole-body counters are administered annually. These counters are operated 24 hours daily. A count takes one-half hour. The 800 radiation workers receive quarterly lung counts in addition to a periodic urinalysis. Of course, a whole-body count is also administered every time there is an identified potential for internal exposure.

Although not used to infer intakes or internal exposures to workers, the plant has an extensive network of air samplers. This includes three types of samplers. The first is an integrating air sampler located at least in each room exhaust port. With air flows of 50 l/min, 0.1 MPC sensitivity is achieved. These samples are read daily. The second type of air sampler, loccated throughout the work area, includes an alarm unit which triggers at approximately 20 MPC-hrs. The third is an effluent monitor, which is located in each effluent stack and is collected on three-day intervals. These annunciating air samplers are used as warning devices to detect incidents and thus trigger bioassays.

Radiation protection is the responsibility of the Department of Health, Safety, and Environment, which employs 350 people. The Director of Health, Safety, and Environment reports to the General Manager of the Rocky Flats Plant. This Department has six sections -- Operational Safety; Environmental and Occupational Health; Medical; Nuclear Safety; Health, Safety, and Environmental Laboratories; and Risk Management. The Operational Safety Section employs 130 technicians who perform radiation monitoring. The Environmental and Occupational Health Section contains 80 professionals, including most of the 20 health physicists employed at the plant (five certified and an additional number who are completing the two-part certification examination). The Health, Safety, and Environmental Laboratory Section contains 50 people who perform the dosimeter badge reading, radiation sample counting, analytical chemistry, and data management.

Each employee who enters an area in which plutonium is handled receives a core training program which includes a three hour unit on radiation protection. This unit includes a description of levels of risk from radiation. Women receive an additional unit on the risk from radiation to the fetus. Operators receive additional instruction in nuclear safety, plus a three-month intensive training program on a "cold" (i.e., non-radiological) line while awaiting security clearance. Each training course is followed by an examination. Also, the core training is repeated on two-year intervals.

1. Impact of Reduction in W.B. RPG

This limit, in itself, would not have a significant impact at this facility. The maximum external exposure in 1982 was less than 2 rem. Only five individuals have exceeded 2.0 rem/year in the last three years, and none has exceeded 3.0 rem/year. The average measurable exposure in 1982 was approximately 0.5 rem. The facility operates with an administrative limit for external exposure of 2.5 rem/year. When a worker has accumulated an external exposure of 1.25 rem, the individual's work record is reviewed by the health physicist, the individual, and his manager, and a plan is implemented to reduce exposure.

Internal exposures would probably not push anyone over the limits, although this depends upon the way committed dose is handled. About 400 individuals at the plant have measurable quantities of plutonium in them. The maximum effective dose equivalent from internal deposition of plutonium is estimated to be less than 1 rem/year.

2. Impact of Reduction in Accumulated Exposure Limit

The maximum accumulated external lifetime exposure at the plant is approximately 100 rem. There are some individuals who have internally deposited plutonium who would exceed this number, but the amount would depend on the weighting factors selected. If the effective committed dose equivalent from intake of plutonium and the weighting factors suggested by the ICRP were added to these numbers, they would be somewhat higher. The assignment of committed 50 year dose to the year of intake would present serious problems.

Notwithstanding the above, this lifetime additional limit is considered inconsistent with an annual limit and not well justified. Moreover, it has the potential of limiting the employment opportunities for a selected number of workers. Even considering the existing administrative limit on external exposures, workers can receive on the order of 3 rem/year if one includes the effective committed dose contribution from internal deposition of plutonium. This would give a few workers an employment vista of approximately 30 years, considered to be overly limiting. Also, this could seriously affect a worker's chance for continuing employment if he has accumulated a significant lifetime exposure, say 80 to 90 rem. Such high accumulated exposures could well act as a deterrent for new employment.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

There have been hand exposures in excess of 50 rem/year in the past, but currently the maximum annual hand exposures are on the order of 30 rem/year. Currently, approximately one-half of the radiation workers are monitored for hand exposures. The reduced extremity limits could result in the need for additional monitoring of hand exposures, but this is not altogether clear at the present time. In any case, it is felt that there is no technical basis for the reduction in the extremity exposure limits.

Moreover, the reduction in the ICRP-26 organ limit of 50 rem/year to 30 rem/year is not felt to the justified.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Any incident in the production line could make a significant contribution to a worker's annual dose. It is impossible to prevent a small number of "incidents," or unplanned releases from occurring. Should these be considered as accidents which are outside of the purview of radiation protection guidelines and regulations? It is difficult to answer this question and a resolution of this issue is considered to be outside of the scope of this case study.

Assuming that the unanticipated, but frequent incidents are covered by the proposed guidelines, the Range C guidance would have a substantial impact at this facility. To provide real-time coverage for those activities potentially resulting in a release would require a doubling or a trebling of the existing monitoring staff -- from approximately 100 to 200 or 300. H.P. technicians earn $25,000 per year, plus approximately $15,000 for overhead and fringe benefits. Moreover, five to ten health physicists would have to be added to the professional staff at a cost of $35,000 per year for each individual, plus $20,000 for overhead and fringe benefits. Finally, at least 5 technicians would have to be hired for the analytical chemistry group to analyze samples and record data. These technicians earn an average of approximately $25,000 per year, plus $15,000 for overhead and fringe benefits.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The requirements of the Range B guidance are currently being performed at this facility. However, it is felt that the word "oversight" should be substituted for the word "supervision" in the guidance.

6. Impact of Training Requirements

This facility is currently complying with the training requirements in the proposed guidelines.

7. Impact of Guidance for Protection of the Unborn

It is estimated that approximately 10% of the radiation workers are women. At present, if a female radiation worker declares to her supervisor that she is planning to get pregnant, another job which does not involve the handling of radioactive materials is found for her if she requests. In any event, a radiation exposure potential analysis is conducted. If she gets pregnant within six months, she is kept out of radiation work during the term of the pregnancy, and if she is breast feeding, she is kept out of radiation work for an additional 12 months after the baby is born. If she does not get pregnant within six months, she returns to her original job. She can request an additional six months away from radiation work if she obtains the concurrence of her physician. The major reason for this stringent policy goes beyond the protection of the unborn. If an individual receives a significant intake of plutonium, he/she voluntarily receives a dosage of DPTA, a chelating agent, to clear the plutonium from the body. This compound is teratogenic, and thus could well produce a malformed fetus. Thus it is advisable to avoid the possibility of administering it to a pregnant female.

Thus this facility is essentially in conformance with Alternatives a and b of the guidance for the protection of the unborn. If Alternative c were promulgated, the roughly 80 female radiation workers would be restricted to certain jobs in which the risk of plutonium intake is insignificant and the external fields are well below 0.2 rem/month. Also, additional monitoring would be required. Although this program would have some impact on current operations, the costs would not be excessive.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

The internal exposure provisions of the proposed guidelines would cause a major problem at this facility. The current method for restricting internal exposures at this facility is based upon the maximum permissible body burden, derived from ICRP-2. This limit was derived from a maximum annual dose to the bone of 30 rem/yr, which in turn goes all the way back to the original radium-equivalent standards. From this dose limitation, a body burden of 40 nCi for plutonium-239 was derived, and it is this body burden that is used as the primary standard. A secondary standard for the concentration of plutonium in air, $2 \times 10^{-12} \mu$ Ci/ml was derived from this primary standard. Although a lower dose limit (15 rem/yr) applies to the lung, this is derived largely from insoluble plutonium, resulting in less restrictive MPC's. Thus, the soluble limits are used for compliance, since both soluble and insoluble plutonium are found in the facility.

The maximum permissible body burden of 40 nCi has historically been the primary standard for limiting the internal exposure from plutonium at this facility.[1] Bioassay, including both urinalysis and lung counting, has been used as the method for measuring body burden. For "clean" plutonium (relatively free of americium-241), the limit of sensitivity for bioassay is 30 nCi, roughly three-quarters of the limit. For aged plutonium (roughly 1,000 ppm americium-241), as little as 2 to 4 nCi can be detected in the body, or roughly 10% of the limit. Fortunately, almost all of the plutonium handled at this facility is aged with americium to a level suitable for lung detection.

IPRC-26 shifted the emphasis to the intake in each year which, in the aggregate over 50 years, would result in the limiting dose to the bone.[2] This limiting annual intake is called the ALI (allowable limit of intake), and is a small fraction of the maximum permissible body burden. In fact, for soluble plutonium-239, the ALI is 200 Becquerel, or approximately 5 nCi. Using urinalysis as the bioassay method, it is not possible to measure this quantity until at least the seventh year of continuous intake (assuming pure soluble plutonium and one micron particle size). With lung counting, it is not possible to do even this well. (Pure plutonium emits X-rays of 13, 17, and 21 kev.)

It is instructive to calculate the effective committed dose equivalent from 1 ALI of soluble plutonium. This is done below.

Organ	Annual Committed Dose Equivalent (rem)	Effective (weighted) Committed Dose Equivalent (rem)
Gonads	0.63	0.16
Red Bone Marrow	3.9	0.47
Lung	0.32	0.04
Bone Surfaces	48.38	1.45
Liver	10.58	0.63
Total		2.75 rem

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[1] Actually, a limit of 20 nCi, a factor of two below the maximum permissible body burden, was maintained as an administrative limit.

[2] In addition, the non-stochastic limit was increased from 30 rem to 50 rem. The philosophy at this facility, however, would be to maintain the 30 rem limit.

Thus, the intake of 1 ALI plus a relatively small amount of external exposure would bring a worker precariously close to the limit.

Air monitoring, on the other hand, is capable of detecting smaller fractions of the limits. For plutonium-239, the limit of sensitivity of air monitors is approximately 2 x $10^{-13} \mu$ Ci/ml, or approximately 10% of the soluble limit. However, it is not appropriate to rely on integrated air monitoring data (MPC-hrs.) to assign internal doses from the inhalation of plutonium. The specific activity is so high that the air monitoring data may not be at all indicative of the intake. The data may be used as a trigger for bioassay, but not as a quantitative measure of intake or dose. In order to quantitatively use air monitoring data, a time-dependent correlation would have to be drawn between the concentration of plutonium at the actual breathing zone of the worker and that of the monitor itself. This is not possible. Moreover, lapel air samplers are not useful in this regard because the volumes of air sampled are too low and people can't wear them where they ought to.

Is there any new technology which will permit measurements down to the levels of the ALI's? For lung counting, a factor of at least 10 in sensitivity reduction would be needed, and there is nothing on the horizon that would improve the sensitivity by more than a factor of roughly 1.5. Significant improvements in sensitivity are potentially available for urinalysis, possibly permitting the detection of an intake equivalent to an ALI. But this will not be sufficient to track an individual during an annual cycle.

Thus, if the EPA guidelines were to be promulgated, it would be necessary for this facility to seek an exception from DOE in order to keep operating. This would not be necessary because the proposed limits are currently being exceeded. To the contrary, the facility is well within the proposed limits. It is because it would not be possible to demonstrate compliance with the current or anticipated state-of-the-art bioassay technology. If an exception were not made in the requirement to demonstrate compliance, this facility would have to shut down and a new absolutely sealed facility would have to be constructed. Although the feasibility of constructing such a plant has not been thoroughly demonstrated, a rough cost estimate of $2 billion has been made.

Although several of the European and Asian countries have adopted the ICRP-26/30 prescription, most of them are having the same problem in demonstrating compliance that this facility would have.

Automating the computation and records system for the proposed guidance would not result in significant costs. The facility already has considerable automation along these lines; both external exposure and organ burden in nCi are reported annually. Minor modifications in software would be required.

One additional feature of the proposed guidance, although not limiting in terms of compliance, is felt to be unrealistic. Because the guidance requires the computation of the 50-year dose commitment, doses to the individual would be debited to his record well before they are actually received. This is felt to be misleading as well as technically incorrect. Moreover, whereas the original ICRP-2 standards were derived on the basis of a fixed 50-year window, the 50-year window keeps moving in the current proposal. Thus, a 50-year dose commitment is still assigned, even for a worker who is close to the end of his career. This is not appropriate because the older worker will not receive this actual 50-year dose commitment during his lifetime.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

Costs associated with reduction in the external exposure limits were examined a number of years ago for DOE. These studies indicated that if administrative controls alone were used, there would be zero costs associated with a reduction to 2.5 rem/yr. To further reduce the limit to 1.0 rem/yr., the costs were estimated to be \$1.7 M/yr. (1978 dollars) if administrative controls alone were used. Finally, reducing the limit to 0.5 rem/yr. administratively was estimated to cost \$10 M/yr. (1978 dollars).

The costs of reducing external exposures using facility modifications were also examined. These were estimated to be \$6.5 M to reduce the limit to 2.5 rem/yr., \$215 M to reduce it to 1.0 rem/yr., and \$1.4 billion to reduce it to 0.5 rem/yr. All of these estimates are one-time costs expressed in 1978 dollars.

H.2 IDAHO NATIONAL ENGINEERING LABORATORY (INEL)

This site, formerly known as the National Reactor Testing Station, contains a number of facilities operated for the Department of Energy by four contractors — EG&G, Exxon, Westinghouse, and Argonne National Laboratory. Westinghouse operates several prototype reactors for the Naval Reactors Program. They have their own radiation protection program for approximately 1,000 employees plus transient personnel in training. Argonne/West, which runs EBR-II, the hot cells and the Zero Power Reactor (ZPR) facilities, also employs approximately 1,000.

This case study is confined to the EG&G and Exxon operations at INEL. EG&G, with approximately 3,500 employees, operates the test reactors at the site. Exxon, with approximately 1,100 employees, operates the chemical processing plant. Together, they employ approximately 70% of the permanent employees at the site.

EG&G operates the following three test reactors at the site:

1. The Advanced Test Reactor (ATR), a 250 MW(t) tank reactor started up in 1968.
2. The Power Burst Facility (PBF), an open tank transient reactor capable of operating at 28 MW(t) and completed in 1973.
3. The Loss of Fluid Test (LOFT), a 55 MW(t) pressurized water reactor started up in 1978.

Approximately 800 out of the employment force of 3,500 are radiation workers. A radiation worker is defined as an individual who goes into the site area on a regular basis.

The chemical processing plant, operated by Exxon, is an enriched uranium reprocessing facility. Although a new waste calcining facility is in place, most of the plant is approximately 30 years old. The plant processes enriched uranium from all over the world, including nuclear navy fuel. Of the 1,100 employees, approximately 900 are considered to be radiation workers.

Although each contractor is ultimately responsible for its own dosimetry, the dosimetry itself is performed by the Radiological Environmental Sciences Laboratory (RESL), an organ of the Idaho Operations Office of the Department of Energy. Additionally, RESL has the legal recordkeeping responsibility. RESL also obtains exposure histories for new contractor employees. RESL performs dosimetry services for Argonne/West as well as EG&G and Exxon. It also services the Grand Junction operations of DOE, the West Valley Demonstration Project, and Sandia West.

External exposures are monitored using TLD's which are normally read monthly. At the contractor's request, RESL will also provide more frequent readings, daily if necessary. Extremities are also monitored on a case-by-case basis. Hands are the most common, but occasionally monitoring is provided for other parts of the body. Exposure recordkeeping is completely automated. Records contain worker I.D., age, sex, monthly dose, annual accumulated dose, lifetime dose, and bioassay data.

EG&G monitors somewhat more than half of its 3,500 employees for external exposure. It maintains a 500 mrem annual administrative external dose limit. If a higher dose for any individual is requested, approval must be obtained by the individual's supervisor and an official from the safety division. The requested limit becomes a "goal" which goes into the individual's and company records. The highest goal in recent memory was 3 rem/yr.

Exxon monitors all of its 1,100 employees for external radiation exposure. It maintains a 3 rem annual administrative limit and a 100 mrem weekly administrative limit. A control point is maintained at 80% of the annual limit (2.4 rem). In addition, an ALARA program is in existence in which each group is allotted a man-rem budget which is not to be exceeded. In 1982 (based on results through September) five out of the nine groups at the facility were under their ALARA budgets. Overall, the collective exposure was less than 70% of the budget. (For all of 1981, the collective exposure was 30% of the budget.)

The external dose distribution for each contractor in calendar year 1981 is given below. The collective exposure for EG&G was approximately 110 person-rem. (The previous 5-year average was approximately 220 person-rem per year.) The collective exposure for Exxon was roughly 150 person-rem.

EXTERNAL W.B. EXPOSURE DISTRIBUTIONS FOR THE YEAR 1981

Exposure Range (rem)	Number of Individuals Monitored EG&G	Exxon
None	1,357	627
0.001 - 0.100	695	199
0.100 - 0.250	148	95
0.250 - 0.499	66	75
0.500 - 0.749	17	51
0.750 - 0.999	11	25
1.000 - 1.999	6	28
2.000 - 2.999	0	0
3.000 - 3.999	1	0
4.000 - 4.999	0	0
Greater than 5.0	0	0
Total	2,301	1,100

RESL also performs bioassays, on request, for contractor employees. These include urinalyses, fecal analyses, whole-body counts, and lung counts. The contractors are provided data on specific activity by radioisotope. They are responsible for converting these data to dose and/or percent body burden.

Whole-body counts are taken for new and departing employees of EG&G. Annual counts are taken for a few hundred employees who work in areas in which uncontained activity is known to exist. A very few employees, mostly those in waste handling, must submit a fecal and urine sample and obtain a chest count annually. Most other bioassays are performed on an as-needed basis, when there is evidence of exposure either from smears or air sampling results. Over the past three years, there have been only three employees with measurable intakes, two of which had accumulated less than 10% of the dose limits. (DOE Order 5480.1A, Table 1.)

Because of the relatively high potential for internal exposure in chemical processing of nuclear fuels, Exxon has a more extensive program for monitoring internal exposures. Of the 900 radiation workers, 260 are routinely monitored annually with two whole-body counts, one urinalysis, and one fecal analysis. These 260 individuals include most of the maintenance personnel, the operators, and the radiation protection personnel. Of the remaining radiation workers, those with non-penetrating exposures in excess of 50 mrem (indicating potentially loose contamination) are given an annual whole-body count. Finally, bioassays are performed in the event of incidents, which are flagged by an extensive air sampling network.

Last year, roughly 30 individuals had measurable internal exposures, most of which were on the order of a few hundred mrem per year. The main problem is plutonium-238. Each measurable intake is analyzed extensively for organ dose. ICRP-30 methods are now used. An 18-page report is not uncommon.

The EG&G radiation safety program resides in the Health and Safety Division. The Operational Safety Branch with a complement of 30 technicians (including H.P. technicians), is ultimately responsible for radiation protection in the field. Technical support is provided by the Technical Safety Branch which employs nine health physicists (two certified). There are eight additional professionals in the Department who are equivalent in background and experience to health physicists.

Radiation safety at Exxon is the responsibility of the Radiation and Environmental Safety Section of the Quality Assurance, Safety, and Security Department. This section contains 34 H.P. technicians and approximately 10 professional health physicists (none certified). There are an additional 4-5 health physicists in other parts of the company.

Also, the DOE Radiological Environmental Sciences Laboratory, which performs dosimetry services for the contractors, employs three professional health physicists (none certified).

EG&G requires all new employees to participate in an orientation session which lasts a full day. One to two hours of this session are devoted to radiation protection. Although there is some qualitative material presented on the risks from radiation, there is no quantitative discussion. Radiation workers receive additional instruction in radiation safety, largely on protective measures (i.e., clothing, respiratory protection, and survey instruments), which occupies the good part of a day. This session is updated annually. Both the orientation session and the protection measures session are followed by an exam. Finally, before a worker is permitted unescorted access to a particular facility, he receives on-the-job training at that facility, including a unit on health physics.

The Exxon training program is basically the same as that of EG&G, except that there is only one facility.

1. Impact of Reduction in W.B. RPG

Both contractors are operating well within the 5 rem/yr. proposed limit, even considering the contribution of internal dose. Thus there would be no impact from the revised RPG.

2. Impact of Reduction in Accumulated Exposure Limit

The highest accumulated external dose is 70 rem, for an Exxon employee. If effective committed dose equivalent were added to the external dose, this employee, and possibly others at the chemical processing plant, could possibly be over the 100 rem limit. However, given current annual administrative limits, it is unlikely that this guidance would have any impact in the future, except under conditions of a severe accident. If another accident similar to SL-1 were to occur, workers could potentially receive a significant contribution to the 100 rem lifetime limit, and thus effectively be precluded from pursuing their careers. This would appear to be grossly unfair.

3. Impact of Proposed Guidance Relative to Extermities and Individual Organs

Hand exposures are not routinely monitored by either EG&G or Exxon unless a task is performed for which there is a potential for extremity doses in excess of 10% of DOE limits. A few years ago, a sample of hand exposures was taken at the chemical processing plant and quite a few exposures were in the range of 7-10 rem/yr. Although it is unlikely that anyone is receiving an extremity exposure of 50 rem/yr., extremity monitoring would have to be performed to assure that this is the case. This conclusion is strengthened by the fact that given the proposed guidelines, the actual extremity limit is 30 rem/yr, not 50 rem/yr, since the skin limit would prevail in the eyes of the compliance officials. The discrepancy between the skin and extremity limits is seen as a limitation of the proposed guidelines.

It is estimated that approximately 100 employees of EG&G and 200 employes of Exxon would have to be monitored. However, hand exposures are not readily retrievable from the current RESL recordkeeping system. Thus, in addition to the increased monitoring requirements, there would have to be additional software development on the recordkeeping system.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Even though there are very few exposures in excess of 1.5 rem/yr. for either contractor, there is the potential for such exposures and thus it was felt that the word "anticipate" applies to both operations.[1] Each contractor issues approximately 1,000 Safe Work Permits per month. A Safe Work Permit is issued for those situations in which written procedures do not exist, unusual hazard potential is involved, or specific DOE or EG&G directives require its use. It is possible for a worker to receive 100 mrem exposure for about 75% of these Safe Work Permits. (It was generally agreed that 100 mrem is "significant.") Thus there are, on the average, roughly 30 to 50 tasks daily that would require "supervision" under the proposed guidance.

At present, an H.P. technician covers, on the average, approximately 8 to 10 tasks per day. To accommodate the Range C guidance, the complement of H.P. technicians would have to be doubled or trebled at each facility. Currently, EG&G employs 38 H.P. technicians and Exxon employs 34 H.P. technicians.

Thus, between the two contractors, anywhere from approximately 70 to 140 H.P. technicians would have to be hired to comply with the Range C guidance. An H.P. technician earns between $20,000 and $25,000 annually. If fringe and overhead is added, the fully loaded labor rate is approximately $60,000/yr. Of course, this is not the strict interpretation of the guidance, which would require supervision by health physicists. EG&G does not believe that hiring 70-140 H.P. technicians or requiring health physicists to monitor each task is feasible.

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[1] "Likely," "potential," and "anticipate" are three words frequently used to characterize future exposures. "Likely" has a DOE definition, but "anticipate" does not. It is felt that the regulators would equate the two, in which case "anticipate" applies to both operations at INEL. The reason for conservatism in the interpretation of these terms is that these are R&D activities, in which each task is different and anything is possible.

The opinion was expressed that the guidelines' approach to ALARA is counterproductive and unnecessary for these facilities. The current program is oriented toward individuals, not tasks, and is quite effective. The proposed three-tiered system is not felt to be an effective way to protect individuals. In fact, it could well increase total exposures, due to the increased number of personnel exposed during each task.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

Both contractors are fully in compliance with the provisions of the Range B guidance.

6. Impact of Training Requirements

Both contractors are in compliance with the training requirements, with the possible exception of a unit on quantitative levels of risk. Plans are currently underway to address this topic.

7. Impact of Guidance for Protection of the Unborn

Both contractors, which employ in the range of 10 to 20% females, are in compliance with the proposed Alternative a of this guidance. The orientation manuals have sections on the risks of radiation exposure to the fetus. If a woman announces to her supervisor that she is pregnant, she can be moved to another job involving little or no radiation exposure. There have been several cases in which this system has worked. For many jobs in which exposures exceeding 500 mrem in nine months are not likely, the woman can remain in her current job, if she so chooses, and she will be double badged and more frequently monitored. H.P. technicians, however, have to be moved to other jobs.

Alternative b would be considerably more difficult to implement. It might be possible to keep the monthly exposure to some H.P. technicians below 200 mrem, but this would take a lot of supervisory time. Also, some men would consider this Alternative to be discriminatory. It could cause morale problems. If there were a lot of women who were desirous of becoming pregnant, this alternative could become costly or involve labor disputes because there are not enough non-radiation jobs to go around.

Alternative c would make the issue easier to deal with, in a sense, because it is mandatory. In essence, this would prevent women from being H.P. technicians, operators, or maintenance personnel. Thus, this could be viewed as discriminatory toward females. The EEO office and the courts would have a great problem with this alternative.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

There are two major impacts of the proposed ICRP-26/30 system of dose limitations. The first is the elevation of currently insignificant internal exposures to the realm of potential significance. As an example, the 1981 incident at the chemical processing plant, in which 22 workers received measurable intakes of radionuclides (75% Pu-238, 15% Pu-239, and the remainder Sr-90 and U-234), was subjected to the new system.

According to the existing system, in which the actual annual dose to an organ is compared against the maximum permissible dose, the average lung dose was less than 2% of the limit (less than 300 mrem/yr compared against 15 rem/yr.). The maximum lung dose was less than 6% of the limit (900 mrem/yr. compared against 15 rem/yr). Using the ICRP-26 system, the average individual's committed weighted internal dose equivalent was 6% of the limit and the maximum was nearly 20% of the limit. These calculations are shown below.

Dose Equivalent in mrem

	Average Exposed Individual		Maximum Exposed Individual	
Organ	50-Year Committed Dose Equivalent	Weighted Committed Dose Equivalent	50-Year Committed Dose Equivalent	Weighted Committed Dose Equivalent
Lung	1,096	132	3,380	406
Liver	685	41	1,840	110
Bone Marrow	301	36	685	82
Bone Surface	3,386	102	11,300	339
Kidney	26	2	4	—
Gonad	20	5	108	27
Total		318		964

The average external dose to these 22 workers in 1981 was 407 mrem, or 8% of the 5 rem limit. Thus, on the average, the effect of the internal contribution is to increase the effective dose equivalent to 725 mrem, or 15% of the 5 rem limit. The maximum exposed individual's external exposure was 946 mrem (or about 20% of the limit); the effect of this individual's internal exposure was to increase the dose equivalent to 1,348 mrem (or about 27% of the limit). The worker with the maximum weighted committed internal exposure received relatively low external expsoure (262 mrem), so that his effective dose equivalent was only about 25% of the limit.

The second major impact of the ICRP-26 system of dose limitations relates to the necessary time frame to make an internal dose commitment determination. Quantitative measurements require multiple samples over relatively long periods of time. This is necessary in order to track the clearance in the body, so that a 50-year dose commitment can be assigned. It may take several weeks, or even months, to assign a dose commitment. In the meantime, if the dose is expected to be significant, it may be necessary to restrict the activities of a worker. The problem is most significant toward the end of a calendar year, in which a worker may have accumulated a relatively large dose up to that date, and the additional internal exposure might cause him to approach the limit. Until the internal dose is assigned, this worker's activities may have to be curtailed.

The only way to detect the intake of relatively small quantities of plutonium is with fecal analysis. Using this method, it is relatively easy to detect 50 Becquerels (1.4 nCi, or approximately 25% of an ALI for soluble Pu-239) on a routine basis and 10 - 20 Becquerels (0.27 to 0.54 nCi, or approximately 5 - 10% of an ALI for soluble Pu-239) in the event of an known incident. The occurrence of the incident is determined by a combination of air concentration data and smear samples. However, multiple fecal samples have to be taken (a messy and unpopular procedure) and considerable analysis must be performed to assign a dose commitment.

Air sampling is useful for the detection of incidents, but it is not appropriate for assigning doses to workers. The relationship between air sampling data and actual internal dose is tenuous at best. Studies at Harwell are quoted that indicate that radiation doses indicated by a fixed sampler may differ from the doses actually received by a worker by a factor of 100 or more. Thus bioassay data are relied upon exclusively for the assignment of internal exposures.

The limit of sensitivity of the fecal analysis is $10^{-8} \mu$ Ci/sample. This facility is probably at the state-of-the-art in internal dosimetry. Over the past couple of years, a large number of improvements in technique have been instituted. It is estimated that the cost of making these improvements has been approximately $300,000.

It is estimated that an increase in resources of about one man-year per year would be required to support the several hundred workers at the chemical processing plant. Some small changes in the dose tracking software would have to be made, but this would involve only a few man-months of effort. There would also have to be a lot of retraining of technicians, and revisions to manuals and procedures.

A major philosophical problem with the ICRP-26 system is the assignment of a full 50-year dose commitment from internal deposition, even for older workers. A 55-year old worker is not likely to receive a full 50 years of internal exposure. There should be a provision for age dependence.

A number of the changes made by EPA to the ICRP-26 system are viewed negatively. Although the rationale for changing the organ weighting factors is understandable, the change was not worth it in consideration of the inconsistencies generated with the literature and the rest of the world. The quantitative differences brought about by the changes cannot be detected anyway with existing sensitivities. Also, definitions of new acronyms (i.e., RIF rather than ALI's) is seen to be counterproductive. Finally, the lid on existing limits is felt to be technically incorrect.

The wording of Recommedation 3.b is felt to be confusing — " H_i is the annual dose equivalent and committed dose equivalent to organ;." Does this mean that the 50-year committed dose equivalent is not to include the present year's contribution?

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

A study of the anticipated impact of reduced external radiation exposure limits on DOE facilities was published by DOE in February, 1981 (DOE/EV-0045 (Rev. 2/81)). Since these contractors contributed to this report and support the information given in the report, reference should be made to this document to obtain the impact of reduced exposure limits.

I.1. RELATIVELY NEW BWR

This relatively new boiling water reactor shares a site with a twin unit which went into operation approximately two years earlier. Each unit has a net electrical output of 780 MW(e). The newer unit has operated at an average capacity factor of approximately 65% since inception of operations.

The station (both units) has a permanent staff of approximately 660 personnel. During normal operations, an additional 1,000 personnel, from utility headquarters and contractors, supplement the permanent staff. During outages, which are scheduled on an 18-month cycle and typically occupy 10 to 12 weeks time, the station complement roughly equals 2,400. The average annual salary of plant personnel is $25,000, including an overhead factor of 12%. Contractor personnel cost $20 per hour, on the average, including overhead to account for radiation protection, security, etc.

The radiation safety organization on-site, which handles radwaste management and plant chemistry as well as radiation protection, has a staff complement of approximately 130 people. Although the group is responsible for some conventional sanitary engineering and industrial hygiene functions, the vast majority of the work is concerned with radiation safety, both on-site and off-site. The manager of the radiation safety unit reports to the manager of plant operations, and has four first-line supervisors (professionals) reporting to him. During an outage, approximately 40 contractor personnel supplement the permanent station radiation safety personnel.

Only one individual in the radiation organization is a certified health physicist, although three other health physicists are studying for the certification exam and should be able to become certified. In total, anywhere from 12 to 20 professionals at the plant are equivalent in background and training to health physicists. In addition, there are approximately 15 professionals at the corporate headquarters who are equivalent in background and training to health physicists.

Dosimetry is handled in-house at the plant. All personnel who enter a posted area are required to wear TLD's which are read monthly (more frequently during an outage) and pocket ionization chambers which are read weekly. The personnel dosimeters do not have neutron capability. Neutron doses are estimated from area exposure rates determined by frequent surveys using BF_6 counters. The external exposure distributions for both units in 1981 are given in the Table. On the average, the collective dose during non-outage periods is approximately 150 to 220 man-rem per month for both units. During an outage, 350 to 400 man-rem per month is typical.

Internal dosimetry is performed using a whole-body counter which is owned and operated by the facility. A whole-body count is obtained for each new employee, upon discharge (even for transient workers used only for an outage), and annually for permanent station personnel. Counts are also obtained if MPC-hours exceed 40 in a 7-day period and for an incident resulting in potential internal contamination. It is estimated that roughly 5,000 whole-body counts are taken annually (each requiring approximately 10 to 20 minutes of counting time). Fecal and urine analyses are performed only in the event of an incident.

Air monitoring is routinely performed to determine the need for respirators. The station (both units) has 10 to 15 continuous air monitors, approximately 40 low volume air samplers and roughly 25 high volume air samplers. Respirators are required for any area in which airborne concentrations exceed 25% of MPC. However, MPC-hour records are not routinely maintained, as in many other plants. Thus, whole-body counting is used exclusively for estimating internal exposures.

Last year, the maximum internal exposure was less than 10% of the maximum internal organ burden. On the average, workers received less than 1% of the maximum.

A new training program is currently being implemented. The program has three levels of instruction. At the first level, personnel get eight hours of instruction in radiation protection, security, and fire protection. Approximately 50% of the time is devoted to radiation protection. The second level, which is given to anyone who is likely to be a long-term radiation worker at the plant (but still requires health physics supervision), provides eight hours of instruction in radiation protection. The third level is directed to the worker who can provide his own health physics supervision, and involves approximately 40 hours of instruction. It is estimated that approximately 300 permanent station personnel will be required to receive instruction at this level. All three levels of instruction include, to various levels of detail, information on risk from radiation exposure. It is estimated that the initial cost of developing this training program was roughly $50,000. The continuing annual costs are expected to be approximately $60,000.

TABLE

EXTERNAL WHOLE-BODY DISTRIBUTIONS FOR 1981 (BOTH UNITS)

Exposure Range (Rem)	Numbers of Individuals
No Measurable Exposure	1,275
Measurable Exposure less than 0.10	1,647
0.10 to 0.25	539
0.25 to 0.50	365
0.50 to 0.75	222
0.75 to 1	161
1 to 2	431
2 to 3	272
3 to 4	168
4 to 5	48
5 to 6	1
Greater than 6	0
TOTAL	5,129

1. Impact of Reduction in W.B. RPG

This annual limit is already company policy. The limit can only be exceeded with the consent of the Vice-President. In fact, the company currently has a goal of 4 rem for the annual limit. The only problem area is that of contractor personnel late in the year, when a number of them have either accumulated exposures close to the 5 rem limit or have exceeded the limit. The company makes it clear to contractors that it is unwilling to exceed the 5 rem annual limit. Some of the contractors are unhappy with this, but they reluctantly accept it.

2. Impact of Reduction in Accumulated Exposure Limit

The accumulated exposures for some of the company employees are approaching 30 rem, and some of the contractor employees have lifetime exposures which exceed 50 rem. It is highly unlikely that exposure of a company employee would approach 100 rem over a lifetime. Therefore, there would not be expected to be impact from this guidance.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Extremity monitors are issued to workers if contact exposure rates are 500 mrem/hr. in excess of general area readings. However, with the occasional exception of radwaste handling, extremity exposures are generally not any higher than whole-body exposures. Thus, there will be no impact from the revised extremity exposure limits.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Coverage by an ANSI-qualified H.P. technician is currently provided for all jobs in which exposure levels exceed 1.0 rem/hr. To cover all jobs at which exposure levels exceed 100 mrem/hr. (defined, somewhat arbitrarily, as the exposure level for which a "significant" contribution might be made to an "anticipated" annual exposure of 1.5 rem) would require the addition to the staff of approximately 20 ANSI-qualified technicians. An ANSI-qualified H.P. technician earns $2,000/mo. plus approximately 15% supplement for nuclear personnel plus as much as 400 hrs. of overtime at time and a half.

Approximately 70% of the H.P. technicians have bachelor's degrees, and it was felt that the ANSI-qualified H.P. technicians (6 years experience required) could potentially pass the H.P. certification examination if they put in enough study. Thus the ANSI-qualified technicians are probably equivalent in experience to health physicists. Besides, the only feasible approach to satisfying this guidance is to use technicians as "radiation protection professionals," since there are not enough health physicist around to supervise and monitor in accordance with a literal interpretation of the guidance. In fact, most nuclear power plants do not have a certified health physicist on the staff.

It was pointed out that this plant is approaching radiation protection in a completely different direction than the proposed Range C guidance. The intent of the level 3 training is to qualify the individual worker to be his own H.P. technician. It is felt that the 40 hours of instruction provided at level 3 will be sufficient to accomplish this.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The requirements of the Range B guidance are currently being satisfied.

6. Impact of Training Requirements

The training requirements of the proposed guidelines are being satisfied for all three levels of instruction. Even level 1 (8 hours of instruction) includes a quantitative presentation on levels of risk.

7. Impact of Guidance for Protection of the Unborn

Females constitute 5% to 10% of the permanent station personnel and approximately 20% of the contractor personnel. The pregnancy rate has been surprisingly low — 3 to 4 out of several hundred female employees. Currently, when a pregnancy is announced, the pregnant female is removed from jobs involving radiation exposure and is placed in another job outside of the posted areas. This policy is written in the corporate handbook.

Therefore, the company is currently operating within a, stricter (zero exposure to the fetus) and a mandatory version of Alternative a. If Alternative b were to be imposed, there would probably not be a major disruption to operations. The legal staff is currently working on a proposal which is quite similar to Alternative c. It is not clear, however, that this proposal will be adopted, because of the conflict with EEO goals.

Adoption of Alternative c would make it somewhat more difficult to operate the plant. However, females currently receive lower exposures than their male counterparts, probably because their supervisors deliberately give them easier jobs.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

As discussed earlier, the company has in-place an extensive bioassay program. At present, the results of the whole-body counting program are expressed in terms of organ burden, and organ dose, using ICRP-2 methods, is only calculated when the organ burden exceeds 10% of the limit. MPC-hours are neither routinely recorded nor used to estimate dose.

Under the proposed guidance for internal exposures the changes in existing practice would be minimal. ICRP-30, rather than ICRP-2 methods would be used to compute organ dose from the results of the whole-body counts. Organ doses would have to be added to external whole-body dose, using the weighting factors prescribed by EPA. However, these changes would not involve significant costs because the company has recently installed an automated dose-tracking system which can easily handle the additional calculations. The cost of this system was $3 to $4 million; however, it is being used at five nuclear units (two of which are located here). It is estimated that the additional software required to implement the proposed guidance would cost approximately $10,000 (again, spread over five units).

The opinion was expressed, however, that the ICRP-26/30 approach is preferable to that approach taken by EPA. Nevertheless, there would be no difficulty in satisfying the DAC's under the EPA, rather than the ICRP system.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

Operation would not be possible if a 1.5 rem/yr. limit were imposed. The required influx of people would be so high that it would not be possible to train them, provide security, etc. Also, the people who exceed 2 rem/yr. are the very specialized workers -- the operators, H.P. technicians, instrument technicians, etc. It would be very difficult, indeed, to replicate these individuals.

Even an exposure limit of 4 rem/yr. would produce serious dislocations. The breakpoint, however, would appear to lie in the range of 3 to 4 rem/yr.

I.2. RELATIVELY OLD BWR

This relatively old boiling water reactor has a net electrical output of approximately 650 MW(e). A pressurized water reactor (PWR) of slightly higher power output occupies the same site as the BWR, and was put into commercial operation approximately five years later. The BWR has operated at a capacity factor slightly in excess of 60% since the inception of operations.

The full-time staff complement at the site is approximately 700, roughly 350 of whom are dedicated to the BWR. Additionally, approximately 1000-1500 contractor personnel are used during a typical outage, which lasts approximately 10 weeks and is scheduled on 12-15 month intervals. The average annual salary of plant personnel is $50,000, including an overhead factor of 45%. Contractor personnel cost $21 per hour, on the average, and an overhead factor of 100% is applied by them to account for management, radiation protection, security, etc.

The radiation safety department at the site services both units. A Radiological Services Supervisor, who manages work in health physics, waste management, and chemistry, reports directly to the Station Services Superintendent, who in turn reports to the Site Superintendent. A staff health physicist and three supervisors report to the Radiological Services Supervisor. Two of the supervisors direct health physics activities at each of the two reactor units, and the third provides dosimetry, calibration, and respiratory protection services to both units. Each of the Supervisors has roughly 6 - 8 personnel reporting to him. With the exception of the staff health physicist, all of the radiological services personnel are technicians. During an personnel outage, an additional 60 to 150 health physics technicians supplement the full-time staff.

At the corporate headquarters, a parallel radiation protection staff of approximately 50 people provide support services to the site (and to a third nuclear power plant at another site), and supplies personnel to the site on an as-needed basis. The staff includes approximately eight professionals with degrees in health physics[1] and 34 additional professionals with equivalent backgrounds in radiological engineering and nuclear engineering.

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[1] None of the health physicists is certified.

Dosimetry for all plants is performed by a unit of the Radiological Assessment Branch at Corporate Headquarters. External monitoring is accomplished using TLD's, which are read monthly during normal operations and on an as-needed basis during outages. Anyone who has occasion to enter plant radiological areas (posted) is monitored. For the site (both units), approximately 2,000 TLD's are issued during normal operations. During outages, the number of TLD's issued may go as high as 5,000.

Distributions of whole-body exposures at the BWR for the past three years are given in the Table. These distributions are synthesized from combined data for both units at the site, and apportioned between the two units on the basis of total man-rem, for each unit.[1] This apportionment is based on the assumption that the exposure distributions, if not the man-rem are similar at the two units. This assumption has been verified by corporate personnel.

During the past three years, the collective exposure at the BWR has been in the range of approximately 1,500 to 2,150 man-rem. This can be compared with the results for the PWR on the same site, approximately 470 to 640 man-rem. BWR exposures are higher, not because the individual exposures are higher, but because the number of tasks and correspondingly, the number of required workers are greater for BWR's than for PWR's. As an example, the number of workers with measurable exposures during the last three years at the BWR was in the range of 2,000 to 3,000, whereas only 500 - 900 workers with measurable exposures were required at the PWR.

Extremities are monitored if area dose rates exceed 100 mrem/hr. and if it is anticipated that the extremity exposure is likely to exceed four times the W.B. exposure. During normal operations, less than 25 extremity monitors are generally issued. During outages, the number of extremity monitors issued may be as high as 200 per week. Eye lens monitoring is generally not performed.

The internal monitoring policy is as follows. Whole-body counting (on a leased unit) is performed for all workers who are issued external personnel monitors at the inception

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[1] Total man-rem for each unit are obtained by aggregating pocket dosimeter data from the Radiation Work Permits. TLD data cannot be disaggregated by individual units.

TABLE

EXTERNAL EXPOSURE DISTRIBUTIONS AT THE BWR FOR THE YEARS 1979, 1980, and 1981

Exposure Range (rem)	Numbers of Individuals		
	1979	1980	1981
Less than measurable	558	715	871
0.0 - 0.10	575	758	809
0.10 - 0.25	238	407	395
0.25 - 0.50	199	447	360
0.50 - 0.75	169	336	246
0.75 - 1.00	136	249	182
1.00 - 2.00	364	645	368
2.00 - 3.00	246	157	125
3.00 - 4.00	69	20	21
4.00 - 5.00	5	5	0
Greater than 5.00	0	0	0

of their employment and at termination. (This may be a a very short period for contractor personnel.) Full-time plant personnel are counted annually. Also, W.B. counts are taken in the event of an incident, if a routine facial frisk indicates high exposures. The cost of a W.B. count is $40. Urinalyses and fecal counts are also performed if warranted by an incident.

Last year the maximum individual MPC-hours were 20. The estimated average for all individuals monitored was less than one MPC-hour. MPC-hours are recorded on Radiation Work Permits, but are not currently readily accessible from the data base. However, a system is being developed and will be implemented in about a year which will readily access W.B. counts and other bioassay results, as well as MPC-hours, and will be able to sort and manipulate the data.[1]

MPC-hours are rarely converted to dose because committed dose equivalents are generally low. Committed dose equivalents were calculated on two occasions over the past year. This is a relatively straightforward analysis using ICRP-30 methods. The corporate health physics' staff is considering the computerization of ICRP-30 dosimetric models.

Instruction in radiation protection principles, including quantitative levels of risk, is given to everyone who is issued a personnel monitor. This instruction lasts approximately four hours and features a slide show and a quiz. Workers who are likely to wear protective clothing or respirators are additionally trained in their use, including a practice fitting. This basic instruction is repeated annually, but the period of instruction may be considerably shorter the second time around.

1. Impact of Reduction in W.B. RPG

No impact is expected from the revised whole-body exposure limit. The company maintains an administrative limit at 5 rem/yr. and since 1979, none of the full-time plant employees has exceeded an annual exposure of 5 rem. In fact, it is estimated that approximately 70% of nuclear utilities maintain an annual exposure limit of 5 rem for their company staff.

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[1] This system is not being developed in response to any specific existing or anticipated regulatory requirement.

The utility has also maintained a 5 rem limit (exposures in excess of 4.5 rem are flagged and individuals who exceed this level are tightly controlled) for contractor personnel. However, the vendors who supply contractor personnel do not necessarily abide by the limits at other utility sites. Limiting contractor personnel to 5 rem/yr at this utility is not believed to entail increased costs, although it may possibly reduce vendor profits.

2. Impact of Reduction in Accumulated Exposure Limit

The highest accumulated exposure for the full-time workers at this utility is approximately 50 to 60 rem. There are several workers in the range of 20 to 30 rem. The problem would be to track the transient workers' cumulative exposures. This would be very difficult, if not impossible.

Several of the transient workers could potentially exceed 100 rem cumulative exposure. Generally these individuals are very late in their careers, and the impact of this guidance on the earnings for these particular workers could be substantial.

This guidance is not viewed favorably at this utility. It is felt to be technically unjustified. Although it would have insignificant impact on the utility, it could have a significant economic effect on a few workers late in their careers. It is felt that the 5(N-18) rem presumption is adequate guidance for lifetime exposures.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

No impact is expected from the revised extremity limits. Over the past few years, the highest extremity exposure was in the range of 10 - 15 rem, to the hand. Usually, extremity exposures are not significantly different than W.B. exposures.

When high beta doses to the eye are anticipated, protective goggles are worn and this does not degrade personnel performance. Since this is generally the only potential for eye lens exposure significantly different than W.B. exposures, it is not anticipated that additional flexibility will be needed.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

The only reasonable interpretation of this guidance is that supervision/monitoring be provided "under the cognizance" of a radiation protection professional. Interpreting the guidance that the radiation protection professional does the monitoring would be "overkill."

Currently, the only time an H.P. technician is required to be physicially present is in a "high radiation area", defined as an area in which the exposure is in excess of 100 mrem/hr. If all workers potentially receiving significant exposures required coverage, it would be necessary to double the number of H.P. technicians from 6 to 8 per unit to 12 to 16 per unit. H.P. technicians earn $9/hr. plus 45% fringe plus overhead.

During outages, the additional 60 to 150 H.P. technicians brought in under contract are enough to provide the one-on-one coverage implied by the guidelines. If actual health physicists were required, however, the hourly rate of $24 for the H.P. technicians would be increased to $50 - $65 per hour, assuming the availability of such a large number of health physicists.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The requirements of the Range B guidance are currently being satisfied.

6. Impact of Training Requirements

Instruction in radiation protection principles, including quantitative levels of risk, is given to anyone who is issued a personnel monitor. Therefore, there would be no impact from the proposed training guidance.

7. Impact of Guidance for Protection of the Unborn

Approximately 2% of the plant radiation workers are females, nearly all of whom are of child-bearing age. The corporate legal department has recently established a policy regarding the radiation exposure of female employees. Openings at the site are advertised as potentially involving radiation exposures in excess of 0.5 rem during any nine-month period. Thus, a condition of employment is the willingness to be exposed to these levels of radiation. This is not seen to be any more discriminatory than the qualification requirements for pole climbers, which are based on certain physical characteristics.

If a female is hired under the presumption that she is willing to be exposed to the same extent as all other workers, and changes her mind afterwards and is not pregnant, this is grounds for discharge under the current policy. If, however, the female becomes pregnant and informs management, she can be temporarily treated as a special case with reduced exposure or temporarily transferred to another job. If neither is possible, she can be terminated.

As of yet, there has been no actual test of the new policy. None of the females at the site has requested a change of status.

The existing policy, therefore, is a mandatory version of Alternative a. If Alternatives b or c were imposed as requirements, females of child-bearing age would not be hired at the plant. The impact at the plant would be small, because of the small percentage of females. The impact on the potential female employees, however, would be substantial.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

This company has historically added internal and external exposures, although the numbers of significant internal exposures have been so low as to render this a moot point. Over the past ten years, the highest estimated internal exposure is on the order of 50 mrem to the whole body.

Currently, MPC-hours are tracked very carefully. The most common radionuclides encountered in the plant air are the activation products — cobalt-58, cobalt-60, manganese-54, and iron-59. Radioiodine is rarely encountered during plant outages, when most of the potential for internal exposure occurs, because of the relatively short half-life. Tritium is generally only a significant problem at plants with stainless steel clad fuel, which is not used at this facility. The opinion was expressed that airborne levels of activity are more a function of plant housekeeping than of plant age.

The revised internal exposure policy is envisioned to have an insignificant impact at this facility. MPC-hours will still be carefully tracked to determine the approximate internal exposure. Whole-body monitoring frequencies are not envisioned to change. The need for dose calculations is expected to still be very infrequent. The calculation of dose with the new models will entail about the same amount of work as previously. Moreover, the health physics' staff is anxious to perform dose calculations using ICRP-30, rather than earlier models.

It is not expected that the accuracy of dose prediction will be limited by the sensitivity of W.B. counting, at least not for the radioisotopes normally encountered at a nuclear power plant. Despite the apparent lack of impact from the revised internal exposure guidelines, disagreement was expressed with the EPA approach. It was felt that our national policy should be in keeping with international standards, and that EPA has little technical justification for deviating from the ICRP-26/30 approach. Also, it was felt that it is inconsistent to drop higher limits, as long as they are derived from the same methodology as lower limits.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

There would be an enormous impact from a reduction of the W.B. RPG to 1.5 Rem/yr. The Atomic Industrial Forum has studied reduced exposure limits, and the AIF position is endorsed by this utiilty. It is felt that it is uncessary to reduce the annual limit below 5 rem/yr. The benefits to health are felt to be exceeded by the costs to individuals' livelihoods.

I.3. RELATIVELY NEW PWR

This relatively new pressurized water reactor has a net electrical output of 850 MW(e). A sister unit of the same output was put into service approximately two years earlier. Both units have been operating at an average capacity factor approaching 80% since inception of operations.

The full-time staff complement at the station (for both units) is 942. Additionally, approximately 220 company personnel are part-time and 536 contractor personnel were used last year. The average salary of plant personnel is $20/hr., which includes an overhead factor of 36%. Contractor personnel cost $34/hr., including an overhead factor of 26%.

The Radiation Safety Department, which is also responsible for waste management, incorporates approximately 55 personnel, with plans to increase staff to approximately 70 over the next year.[1] The current annual budget is approximately $5 million, roughly $3 million of which goes to contractors. Three of the staff members are health physicists, one of whom is certified. One additional member of the plant staff, outside of the radiation safety staff, is certified by the National Registry of Radiation Protection Technologists.

Dosimetry is performed by a unit of the Radiation Safety Department. External monitoring is accomplished using TLD's, which are read monthly during normal operations (more frequently during outages). Anyone who is likely to enter a controlled area (radiation fields in excess of 0.5 mrem/hr) is monitored. Currently, the average number of TLD's issued during a typical month (non-outage) is approximately 1200; during an outage, this increases to approximately 1600. Self-reading personnel dosimeters are also issued to each individual who receives a TLD.

The external exposure distributions for the year 1981 are given in the Table. It is believed that the exposure distributions for in-house and contractor personnel are similar. The collective exposure for both units was approximately 540 man-rem, with an average exposure per worker of approximately 0.21 rem. Approximately 95% of the

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[1] The increase is not related to specific regulatory requirements.

TABLE

EXTERNAL WHOLE-BODY DISTRIBUTIONS FOR 1981
(BOTH UNITS)

Exposure Range (Rem)	Numbers of Indviduals
No Measurable Exposure	990
Measurable Exposure less than 0.10	485
0.10 to 0.25	353
0.25 to 0.50	289
0.50 to 0.75	207
0.75 to 1	101
1 to 2	105
2 to 3	15
3 to 4	0
4 to 5	0
> 5	0

collective exposure was accumulated during the refueling outage, which typically lasts for 11 weeks and is scheduled once every 18 months. These data are typical of the radiation experience at the plant since the first unit went into operation.

Internal dosimetry is accomplished with a leased whole-body counter which is capable of detecting a small fraction of the Allowable Limit of Intake (ALI) for all radionuclides normally encountered at a nuclear power plant.[1] All company personnel are counted when they are initially hired and when they are discharged by the company. Additionally, all personnel who receive external whole-body doses in excess of 0.5 rem are counted annually. Finally, a whole-body count is taken if an individual is exposed to airborne concentrations in excess of 25% of the limits — 10 MPC-hours in a week, based on airborne grab samples taken during all tasks.

Lapel air samplers have been ordered and they will be used in the future for jobs involving significant exposures.

For 1981, the collective internal exposure for both units was approximately 175 man-MPC-hours (corresponding to an estimated 0.4 man-rem whole-body collective dose equivalent) based upon data for 239 workers,[2] out of a total of 2,505 workers monitored. The highest internal exposure was 7.5 MPC-hours; the average for all radiation workers was 0.07 MPC-hours (corresponding to an estimated 0.17 mrem whole-body dose equivalent).

Two types of training are provided to station personnel. For personnel who are not likely to enter controlled areas (and are, accordingly, not monitored), three hours of training in radiation protection are provided annually. For those who are likely to enter controlled areas ("radiation workers"), 1½ - 2 days of training in radiation protection are provided annually. The curriculum includes a unit on quantitative levels of risk (NRC Regulatory Guide 8.29 and the IAEA pamphlet, "Radiation —A Fact of Life"). Training sessions, which incorporate approximately 20 workers, are scheduled twice a week and are conducted by the Training Department and Technical Services Section.

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[1] For example, the sensitivity of the counter for iodine-131 is 2 nCi; a standard man's uptakes is 56 nCi at MPC during a 40-hour week.

[2] Data are recorded whenever a worker performs a task in which the airborne concentration exceeds 0.1 MPC.

1. Impact of Reduction in W.B. RPG

No impact is expected from the revised whole-body exposure limit. This company has been successful in keeping actual exposures below this limit for the 7½ years that the first unit has been in operation. In fact, only one individual has received an annual exposure in excess of 4 rem. Part of the reason for relatively low occupational exposures is "clean fuel" (few leakers). However, some of the success in keeping annual exposures relatively low must be attributed to the maintenance of multi-tiered administrative limits. The weekly limit is 300 mrem. The quarterly limit is 900 mrem, with a 2 rem quarterly ceiling. Monitors are read and records are reviewed at 150 mrem increments above the 900 mrem limit. The annual administrative limit is 4.7 rem, with a ceiling at 5.0 rem.

2. Impact of Reduction in Accumulated Exposure Limit

The highest accumulated exposures for utility employees are in the range of 20 to 30 rem. However, some of the contractor personnel have accumulated exposures as high as 100 rem, and a few of these are in their 40's. Most of these contractor personnel with high exposures are specialists, such as in-service inspectors of steam generators. This proposed limit could potentially interfere with the livelihoods of such individuals. Moreover, these specialists are quite scarce. Sometimes it is necessary to go to foreign countries to obtain this expertise.

Additionally, it is felt that there is no basis for this lifetime limit. Neither the NCRP, ICRP, or any other peer view group has concurred with this recommendation.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

No impact is expected from the revised extremity limits. It is policy to measure extremity exposures where the radiation field exceeds 1 rem/hr. and when the extremity dose rate is estimated to exceed the whole-body dose rate by at least 10%. The highest recollected hand and forearm exposure was 7 rem. During last year's outage, approximately six individuals received hand and forearm exposures between 3 and 4 rem.

The plant is currently in conformance with the 5 rem/yr. limit to the eye lens, so there would be no impact from this provision of the guidelines. To keep within the 5 rem/yr. limit, it is necessary for workers handling some beta sources to wear protective goggles. If the recommendations of the NCRP (15 rem/yr.) or ICRP (30 rem/yr.) were adopted, the use of these protective goggles might not be necessary.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

During normal operations, there are only a couple of jobs in which there exists the potential for exposures in Range C. These are radwaste handling, which is generally monitored by one to two H.P. technicians, and the normal rounds of the operators, which are also covered by H.P. technicians, as appropriate. All of this is trivial, however, when compared with the potential exposures during outages.

During outages, which last on the average approximately 11 weeks, as many as 1,500 workers typically enter the contaminant, and as many as 75 percent of these might receive in excess of 1.5 rem annually. During the outage, as many as 150 H.P. technicians augment the 50 full-time technicians. Even so, it is not possible for these technicians to cover all tasks which might involve "significant" exposures.

There are three possible interpretations of this guidance. In the least strict interpretation, "supervision" would mean control over all of the tasks undertaken by each individual and cognizance over exposure levels (through the radiation work permit system), daily monitoring of actual exposures (by reading pocket dosimeters), and real time coverage during certain jobs in high exposure level fields. This is the existing program and if this is the intent of the guidance, there would be no impact.

In a stricter interpretation, all tasks in which "significant" exposures may be accrued (interpreted to be approximately 100 mrem or greater) would require real time coverage by H.P. technicians. It is estimated that to accomplish this, roughly 50 additional H.P. technicians would have to be retained. Contractors receive approximately $35/hr. for H.P. technicians. During the 11-week outage, H.P. technicians work approximately 84 hour per week.

Although approximately one-third of the H.P. technicians are ANSI-qualified, none of them are equivalent in background of experience to professional health physicists. The strict interpretation of the guidance would require all of the roughly 200 individuals who supervise and monitor in contaminant during the outage to be health physicists or their equivalent. Contractors are paid $70/hr. for health physicists. The feasibility of this interpretation is questionable.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

Both the monitoring and supervision requirements of this guidance are currently being carried out by the Radiation Safety Department. Therefore, there would be no impact from this proposed guidance.

6. Impact of Training Requirements

This is currently being carried out, including instruction on levels of risk.

7. Impact of Guidance for Protection of the Unborn

Approximately 15 percent of the plant personnel are currently females of child-bearing age. Although there exists no formal policy regarding allowable exposures to women who are not pregnant, exposures to women have never exceeded 0.5 rem/yr. This is probably a result of the type of work that females perform plus the inference that females are more highly motivated to keep exposures low ("macho" syndrome).

The company currently operates under a mandatory version of Alternative a. Women are trained to inform their supervisors when they are diagnosed to be pregnant. As soon as the supervisor is notified, the woman is removed from a job which involves potential exposure to radiation and is assigned to a job in a non-controlled area.

To additionally limit female exposures to less than 0.2 rem/mo. would not be a problem, since exposures to women have never exceeded 0.2 rem/mo. Therefore, there would be no impact at this plant from Alternatives b or c.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

This company is already operating in a mode which is in consonance with the internal exposure provisions of the guidelines. If a radiation work permit indicates airborne concentrations in the work area which exceed 0.1 MPC, then the internal exposure (in units of MPC-hours) received during the task is aggregated with the previous exposure in his record. (This step is being automated, independent of any revisions to current regulations.) If the exposure during a 40-hour week should exceed 10 MPC-hrs (25% of the weekly administrative limit), the health physics staff is alerted and a whole-body count is taken.[1] The results of the whole-body count are analyzed by the health physics' staff and converted to dose, using ICRP-2 methods at present. If the estimated organ dose differs from that based on the airborne exposure (in MPC-hrs.), the revised organ dose is entered (manually) into the individual's record. The estimated internal exposure is added automatically to the external exposure to provide an estimate of the total exposure.[2]

The procedure for treatment of internal exposures implied by the proposed guidelines are not expected to differ in any substantial way from current practice. Nomenclature is changed (ALI and DAC vs. MPC), weighting factors differ, and methodology for calculating dose is updated (ICRP-30 vs. ICRP-2). These are not envisioned, however, to involve substantial costs.

Moreover, the proposed guidelines are envisioned to permit more professional judgment and flexibility than the existing regulations. This facility envisions the opportunity to adjust DAC's on the basis of actual, rather than prescribed particle size.

Estimating organ dose from whole-body counting is not envisioned to be a problem for most radionuclides. Some of the beta-emitters could pose a problem. Tritium is not a problem at this plant because the fuel has been relatively "clean." If significant amounts of airborne tritium were present, procedures would require routine urinalysis. Strontium-90, if present in significant quantities, could also pose a problem.

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[1] This occurs rarely; last year, no one received more than 10 MPC-hrs. for the entire year.

[2] The point was made that the summation of dose equivalent attributed to both external and internal sources has always been the foundation of occupational exposure limits. ICRP-1 stated it, and it has been restated by ICRP-6, ICRP-9, and ICRP-26.

Given a significant intake, the major impediment to accurate organ dose estimates is the variability in people. The use of parameters for "reference man" introduces large potential errors for some individuals.

Notwithstanding the relative ease of compliance with the proposed internal exposure guidance, senior personnel at this facility do not agree with EPA's changes in the ICRP-26 formulation. The opinion was expressed that the revised weighting factors are difficult to correlate with the existing literature and are technically incorrect. Moreover, the maintenance of an upper limit on the RIF's at the values currently in use is felt to be indefensible.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

It would be very costly if the limit were lowered to 1.5 Rem/yr. Although most in-house personnel don't receive 1.5 rem/yr., many of the contractor personnel do. The individuals hit hardest would be those with the most expertise (i.e., in-service inspection of steam generators). An example is the vendor crew who inspects the control rod drives. This requires very specific expertise, and it is not possible to do a single inspection without accruing 500 mrem of exposure.

I.4. RELATIVELY OLD PWR I

This is one of two twin PWR's completed in the early 1970's. The net electrical capacity of each of the two units at the site is approximately 775 MW(e). Since the completion of major steam generator repairs, both units have been operating at approximately an 80% capacity factor.

The normal station staff is approximately 600 full-time employees. However, approximately 100 additional workers are completing design modifications mandated by the Three Mile Island action plan. During refueling outages, which last approximately 45 days and are scheduled on 18-month intervals, an additional 50 to 100 workers are generally brought in, mostly from the utility's "travelling maintenance pool." Roughly 30% of the collective exposure at the site is accumulated during refueling. The comparatively low number of additional employees required for a refueling outage is attributed to two reasons. The first is that 10-14 day maintenance outages are routinely scheduled in the spring and fall. These outages, which are not significant from the point of view of collective radiation exposure, reduce the amount of work required during refueling outages. The second reason for the comparatively low number of outside workers during a refueling outage is the overtime policy at the plant. Most of the work during refueling outage is performed by full-time station personnel on overtime. However, this policy also results in exposure distributions which are generally skewed to the high side in comparison with several other nuclear power plants. On the other hand, the overtime policy and the use of the utility maintenance pool results in a relatively low use of outside contractors (except for specialty skills), which may lead to lower collective exposures.

Major ten-year outages are also being planned, which will probably take twice as long as ordinary refueling outages. The collective exposure will also probably be twice as high. These outages will involve a great deal of primary system inspection, as well as inspection of the steam generators and the primary coolant pumps.

The radiation safety department, which is distinct at this plant from the chemistry department, employs approximately 50 people and currently has an annual budget slightly in excess of $4 million. Nearly half of these are professionals, which includes two degreed health physicists (non-certified) and an additional four to five personnel

TABLE

EXTERNAL WHOLE-BODY DISTRIBUTIONS
FOR THE YEARS 1981 AND 1978
(BOTH UNITS)

Exposure Range (Rem)	Number of Individuals	
	1981	1978
No Measurable Exposure	159	1,301
Measurable Exposure less than 0.10	1,095	1,077
0.10 to 0.25	585	215
0.25 to 0.50	363	111
0.50 to 0.75	185	76
0.75 to 1	154	77
1 to 2	597	341
2 to 3	354	147
3 to 4	192	75
4 to 5	101	40
5 to 6	45	24
6 to 7	71	14
7 to 8	9	6
8 to 9	2	0
9 to 10	0	0
10 to 11	0	0
11 to 12	0	0
Greater than 12	0	0
TOTAL	3,912	3,504

who are equivalent in responsibility and experience to health phyicists. The manager of the radiation safety department reports directly to the station manager.

There is also a relatively small health physics support staff at the corporate headquarters. Approximately six professionals, all health physicists (none certified) or equivalent, support this station and another one, also with two units.

External dosimetry at the station is performed with TLD's which are normally read in-house monthly (more frequently when required). The policy is to issue a TLD to anyone entering the restricted area. Additionally, pocket dosimeters are used for running estimates of dose for anyone entering radiation areas. The TLD, however, provides the dose of record. The external exposure distributions for the years 1981 and 1978 are provided in the Table. Exposure distributions for 1978 are included because that is the most recent year in which major work was not involved on the steam generators.

Internal exposures are monitored and controlled by sampling airborne concentrations at eight locations within the plant. Whole-body counting is also performed on all employees at entry and termination, and when air concentration data indicate exposures in excess of 10 MPC-hrs. during any week, or in the event of any suspicion of uptake (i.e., defective respirator, facial contamination, etc.). The station has its own whole-body counter. In addition, 25 workers are randomly selected monthly for urinalyses. The urine specimens are shipped to a vendor for analysis of tritium and fission products. If there is a discrepancy between the implied internal doses derived from MPC-hrs. and the results of bioassay, the bioassay becomes the dose of record.

The main internal problem is radioiodine. An activated charcoal canister is used on respirators to trap iodine, but credit is not taken for the effect of the canister in computing MPC-hrs. for radioiodine. This is because NIOSH does not recognize the effect of the activated charcoal canister on radioiodine. Accordingly, one would not expect a correlation between MPC-hrs. and whole-body counting data for this radioisotope.

Routine statistics on internal exposures are not formally tracked. However, on inspection of the data, the highest internal exposure at the station in 1981 was 25 MPC-hrs. The average for all workers potentially exposed was less than 5 MPC-hrs.

All radiation workers at the plant are instructed in the principles of radiation protection, including information on quantitative levels of risk. Utility employees receive four days of training before they begin work in controlled areas. One full day is devoted to radiation protection and another full day to respiratory protection. Contractor empoyees are provided only one day of instruction, 90% of which is devoted to radiation protection.

1. Impact of Reduction in W.B. RPG

This plant generally has a substantial number of individuals, mostly in-house personnel, exposed in excess of 5 rem/yr. In 1981, there were approximately 125 people with exposures greater than 5 rem, and most of these people were not involved in steam generator work. A number of administrative limits are established to limit exposures at the plant. Individuals may be allowed to receive in excess of 1.25 rem/qtr. as follows. In order to go to 1.5 rem in a quarter, approvals must be obtained from the employee's supervisor and from the manager of radiation protection. An additional approval of the department superintendent must be obtained to go to 2.0 rem/qtr., and the station manager must approve exposures up to 2.4 rem/qtr. Exposures higher than 2.4 rem/qtr. require corporate approval.

If the 5 rem annual limit were promulgated, there would initially be more dependence on contractors and the utility's travelling maintenance pool personnel. Overtime of full-time personnel would be reduced and annual incomes of several plant personnel, particularly operators and mechanics, may drop. Utimately, however, more full-time staff would have to be hired, in consonance with the company policy of limiting the use of contractors.

To estimate the costs of additional personnel is difficult. The best approach would probably be to estimate the impact on the entire industry using a methodology such as that developed by Stone & Webster.

It is not yet clear how utilities would respond to the elimination of quarterly limits. Some might permit workers to get a sizable fraction of the 5 rem annual limit in the first quarter. This might ultimately lead to labor problems, in that these workers could get "burned out" early in the year and be unable to pursue their specialties or collect overtime pay at the end of the year. The only solution to this dilemma might be to establish a quarterly administrative limit of 1.25 rem.

2. Impact of Reduction in Accumulated Exposure Limit

It is estimated that the maximum accumulated exposure for in-house workers is approximately 50 rem, whereas some contractor employees might have accumulated as much as 80 rem. Thus, if the 100 rem lifetime limit were imposed, there might be some career shortening for contractor personnel. The cost impact to the plant, however, would not be substantial.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

There would be no impact from the revised limits for the hands and arms/feet and legs. The highest exposure on record is approximately 10 rem to the hands.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

If the existing Radiation Work Permit system satisfies the intent of the supervision and monitoring requirements of the guidelines, then there would be no impact. However, a literal interpretation of the guidelines calls for real time monitoring. Currently, real time coverage is only required for tasks conducted in radiation fields which exceed 1 rem/hr. If coverage were required for tasks conducted in radiation fields which exceed 100 mrem/hr (generally agreed to constitute a "significant" contribution to an annual exposure of 1.5 rem), the number of H.P. technicians would have to double from 20 to 40. During the 45 day outage, the 15 H.P. technicians under contract would have to be doubled to 30 (assume 84 hrs per week). H.P. technicians earn approximately $25,000 per year plus 25 percent fringe benefits. If actual health physicists were required to provide the coverage, the 20 full-time H.P. technicians would have to be replaced by 40 health physicists at a salary of at least $35,000 per year (plus 25 percent fringe benefits). During an outage, an additional 30 health physicists would have to be hired. Of course, this interpretation of the proposed guidelines is not possible since there are not enough health physicists to go around.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The requirements of the Range B guidance are currently being satisfied.

6. Impact of Training Requirements

All radiation workers at the plant are already being instructed in the principles of radiation protection, including information on quantitative levels of risk. Thus there would be no impact from this guidance.

7. Impact of Guidance for Protection of the Unborn

Ever since the introduction of NRC Regulatory Guide 8.13 a few years ago, this utility has been operating under a mandatory version of Alternative a. It is the responsibility of the woman to announce a pregnancy to her supervisor. The supervisor must inform the radiation protection group. It is then the responsibility of the radiation protection group to limit the dose of the unborn to 500 mrem. Pregnant females are not allowed to work in radiation areas. In other areas, monthly exposures are not likely to exceed 25 mr. So far, there have been about 10 pregnancies and there have been no problems. (Approximately 8% of radiation workers are female). In one case, a woman's exposure was greater than 400 mrem at the time that she discovered that she was pregnant. She was given an administrative job at the same level of pay.

Alternatives b and c would raise the issue of equal opportunity. Even though Alternative b is voluntary, a woman would not be assigned to certain jobs if the possibility exists that she might choose to be reassigned at some time in the future. These jobs include mechanics, operators, and radiation protection. If the Federal government were to impose Alternative c, it would let the utility "off the hook" regarding equal opportunity considerations. The impact on the utility itself would be insignificant, given the low percentage of females working at the plant. It would limit the opportunity for females, however, to be promoted to higher paying jobs.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

The existing internal exposure program is based on recorded MPC-hrs. for compliance. Moreover, if in any one week MPC-hrs. should exceed 10 (25% of the weekly limit), a whole-body count is taken and an organ burden is estimated from the whole-body count. If the estimated organ burden exceeds 5% of the limit, it is documented and reported to the worker. Internal organ dose is not estimated.

If the internal exposure provisions of the proposed guidelines were implemented, two expansions of the existing systems would have to be made. The first would be a major modification to the body burden analysis system, a computer system which converts whole-body counts to organ burden. It also computes 50-yr. dose commitment, but in a very rudimentary fashion. This system originally cost $60,000. To get the system to compute organ doses using ICRP-30 methodology would require a major expansion in both hardware and software, estimated to cost approximately double the original system, or roughly $120,000.

The second system requiring modification is the computer system which handles external exposures. Relying on input organ doses from the revised body burden analysis system, this system would compute the effective dose equivalent. The system originally cost $80,000 for hardware and $100,000 for software. A similar software modification to the one envisioned here took a programmer about three months and cost approximately $10,000. The original contractor for this software is still on-board, so that modifications to the software can be accomplished in a cost-effective manner.

It is envisioned that the link between the two systems would be done manually, providing an intermediate check on the estimated organ doses. The three-four technicians who currently run the body burden analysis system could handle this additional task relatively easily, but they would require additional training. This could be obtained most cost effectively using existing training consultants. An analogous two-week training course relating to changes in the radwaste regulations cost approximately $10,000 to $25,000.

There is one serious problem envisioned in the application of the proposed methodology. This is the treatment of the time-dependence of intake for chronic intake situations.

Some guidance would have to be provided in this area. The problem could be avoided if MPC-hrs. were used to estimate organ doses, but the results would be overly conservative and not at all indicative of actual organ doses.

It is felt that EPA's deviation from the ICRP-26 prescription introduces serious inconsistencies. One aspect of this would be in the computation of exposures to the general public, if ICRP-30 methods were to be used. Also, the lower DAC's resulting from the EPA changes might have a subtle effect on the sensitivity of the measurements, requiring longer calibration times.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

Operation at an annual exposure limit of 1.5 rem/yr. would be virtually impossible. Last year, 1,371 workers, or approximately 35 percent of the total number of workers monitored, received exposures in excess of one rem.

I.5. RELATIVELY OLD PWR II

This is a three-unit station of 860 MW(e) Pressurized Water Reactors. The oldest unit recently completed its 10-year in-service inspection. The average capacity factor of all three units through September, 1982 has been roughly 40 percent. The station is one of three nuclear stations owned by the utility, the second has one unit in operation and another completing construction, and the third station has not been completed. The three stations incorporate seven units.

The full-time staff complement at the station is approximately 1,000. During outages, the permanent staff is supplemented by as many as 500 transient workers and about 1,000 other utility employees. Outages are conducted during refueling operations, which were originally scheduled on a 12-month period, and are being extended to an 18-month interval. A refueling outage typically lasts from two to three months.

The plant has a health physics staff consisting of 80-90 people. During outages, in-house personnel are supplemented by as many as 140 health physics contractor personnel. Five of the permanent staff are professional health physicists. None are certified. The manager of the station health physics group reports to the Superintendent of Technical Services, who reports to the Station Manager, who reports to the Corporate General Manager of Nuclear Stations, who reports to the Vice-President of Nuclear Production.

The radiation protection program at all the nuclear stations is developed by the corporate health physics staff, which consists of eight professionals, two of whom are certified. The manager of the corporate health physics staff reports to a corporate Manager of Technical Services, who reports to the Vice-President of Nuclear Production. Therefore, although the corporate health physics staff sets the overall corporate radiation protection policy, the plant health physics staff has a parallel reporting chain.

External personnel monitoring is accomplished with TLD's, which are centrally processed monthly at corporate headquarters and are issued to almost all personnel who enter the restricted area. Pocket dosimeters are also issued to these individuals who enter the radiation control area (the reactor building and the auxiliary building), but the TLD readings provide the dose of record. The whole-body exposure statistics for calendar year 1981 at the station are given in the Table. The collective exposure at the station during calendar year 1981 was approximately 1200 man-rem.

Internal monitoring is performed by a combination of air sampling and bioassay. Installed and portable air monitors provide area air concentrations which are entered into the Radiation Work Permits. MPC-hours are maintained in the computer data files, together with external exposures, as surrogates for internal dose. The highest recorded intake over the past year was approximately 80-100 MPC-hrs. Only about 100 personnel received measurable internal exposures.

Bioassay is performed with company-owned body burden analyzer chairs. Counts are performed for new employees and non-employees, upon termination, and annually during employment with the company. Special counts are also taken in the event of an incident involving suspected intake, and on a random sample of workers throughout the exposure range quarterly. Whole-body counts are also made if a worker is exposed to more than 35 MPC-hrs. of iodine in a period of one week. From time-to-time, urinalyses are also performed on workers who are potentially exposed to tritium.

During a recent typical quarter involving approximately 2700 whole-body counts, 27 individuals indicated organ burdens in excess of one percent of the maximum permissible organ burden. Two individuals had uptakes of approximately five percent of the maximum permissible organ burdens. (A higher uptake was observed, but this was believed to be anomalous, the result of skin contamination.) At five percent of the limits, a dose analysis is performed using ICRP-2 or MIRD methods. At five percent of the maximum permissible body burden, 50-year organ dose commitments on the order of 200-300 mrem are calculated, depending on the radionuclide involved.

The results of bioasseys are maintained in each individual worker's record. The record, which is not maintained on the computer, includes the whole-body count, intake expressed as percent body or organ burden, and dose (if computed). This information is all entered by hand from the output of the multi-channel analyzer.

Three levels of instruction on radiation protection are provided to station workers. Workers who perform hands-on work in radiation fields, which constitutes the lion's share of station personnel, receive 27 hours of instruction annually. The instruction, which is consistent with the provisions of Regulatory Guide 8.27, includes a section on levels of risk from radiation.

TABLE
WHOLE-BODY EXPOSURES FOR CALENDAR YEAR 1981

Annual Whole-Body Dose Ranges (Rems)	Number of Individuals in Each Range
No Measurable Exposure	820
Measurable Exposure Less than 0.100	945
0.100 - 0.250	371
0.250 - 0.500	338
0.500 - 0.750	195
0.750 - 1.000	138
1.000 - 2.000	331
2.000 - 3.000	121
3.000 - 4.000	6
4.000 - 5.000	0
Greater than 5.000	0
Total	3265

Personnel who may enter controlled areas but are not expected to perfom hands-on work receive up to six hours of instruction annually, including a discussion of risk from radiation exposure. Finally, all other employees who are not expected to enter controlled areas receive an hour or two instruction in radiation protection at the beginning of their employment.

Any employee can by-pass the next annual update of instruction on radiation protection by taking and passing a more comprehensive examination than the regular test.

Training is conducted by a training group at the site. However, the content of the radiation protection instructional program is developed by the corporate and station health physics groups.

1. Impact of Reduction in W.B. RPG

This utility has always maintained an administrative limit of less than 5 rem/yr., and has never had an annual exposure which exceeded this limit. Thus there would be no impact at this plant from the imposition of a 5 rem annual regulatory limit. In addition, exposures to contractor personnel are maintained below 3 rem per quarter and under 5 rem/yr. at this utility's sites.

2. Impact of Reduction in Accumulated Exposure Limit

This guidance is felt to be ill-advised. There are about 150 people in the nuclear power industry who will exceed 100 rem in a lifetime. Most of these workers are highly-trained specialists whose skills are difficult and costly to replicate.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Maximum extremity exposures at the station are generally a few rem per year, a small fraction of the reduced limit of 50 rem/yr. These exposures are received by a small fraction of station workers, possibly about a hundred, who work on steam generators or divers who perform repairs in the spent fuel pools. Therefore, there is not expected to be an impact from the reduced extremity limits.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

This facility currently complies with the Range C guidance. Every radiation worker is tracked continuously by a large control system. An administrative limit of 500 mrem applies to any contiguous 5-week period. If it appears that a worker is likely to receive a significant fraction of the administrative limit, he/she is provided coverage by an H.P. technician.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

This facility currently complies with the Range B guidance.

6. Impact of Training Requirements

All workers who enter controlled areas receive instruction in radiation protection, including a unit on quantitative levels of risk.

7. Impact of Guidance for Protection of the Unborn

This utility is currently operating in consonance with the provisions of NRC Regulatory Guide 8.13, and is thus in conformance with a mandatory version of Alternative a. It is the responsibility of the female to announce a pregnancy to her supervisor. The exposure of the embryo/fetus is then limited, by careful supervision, frequent monitoring, and/or removal from radiation work, to 500 mrem during the pregnancy.

Alternatives b and c are felt to be unfair to women and, for that matter, to men as well. They would limit the ability of females of child-bearing age to get certain jobs at the plant.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

A considerable amount of software development would have to be performed in order to revise the existing automated system in accordance with the provisions of the internal exposure guidance. Approximately one man-year[1] of effort is estimated to be required to change the MPC-hr. calculations to estimates of DAC-hrs. and dose. (A very simple dose conversion scheme is assumed, in which conversion factors are supplied by Agency guidance.) One man-year of a health physics technician is assumed to be required to design the forms to feed the input data into the program. Finally, approximately one-half of a man-year of a professional is estimated for QA of the resulting software and an additional one-half man-year of a professional for training of the health physics staff in the use of the revised software. Thus the total one-time effort for the development, QA, and training associated with the automated records' system is estimated to be approximately 3-man years.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

The costs would be very high to operate within a W.B. exposure limit of 1.5 rem/yr. In 1981, approximately 15 percent of the workers at the plant received annual exposures in excess of 1.5 rem.

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[1] Computer costs are assumed within the manpower estimates.

J. UNIVERSITY REACTOR

This is a 2 MW(t) swimming pool research reactor with MTR-type fuel. Of the approximately 50 U.S. university research reactors in operation, approximately 10 are of this type. The moderator is ordinary light water, the fuel is highly enriched, and the cooling is by forced convection.

The reactor is used for graduate and undergraduate (3rd and 4th year students) nuclear engineering laboratory courses. Additionally, an extensive research program is underway. The most highly funded program is an investigation of the neutron embrittlement of reactor pressure vessel steels. This involves round-the-clock irradiation of samples, requiring three-shift operation of the reactor. Several projects involve neutron activation analysis. A study of radioiodine partition coefficients in water/air systems requires activation of iodine in the reactor. Gamma-ray spectroscopy is underway using beams from the reactor. Approximately a dozen small colleges and universities in the region share the reactor for research and training under a Department of Energy program.

The reactor is located in a separate, relatively remote building on the campus. The reactor room is airtight and serves as a containment around the reactor. The building houses the Nuclear Engineering Department at the University, and accordingly has several offices, classrooms, laboratories, a machine shop, and an electronics shop. Additionally, a small, low-power (approximately 100 w) pool reactor is located in the building for nuclear engineering laboratory courses.

The reactor is one of several facilities at the university under the cognizance of the Radiation Safety Office. The Radiation Safety Office is one of three divisions in the University Environmental Health and Safety Office. With a current budget of approximately $300,000 per year, the Radiation Safety Office employs a Radiation Safety Officer (a health physicist who is also a staff member in the Nuclear Engineering Department), three health physicists (with at least bachelor's degrees and one year of experience), three technicians, and one secretary. None of the health physicists is registered. One health physicist and approximately one-half of a technician are assigned to the reactor facility full time. Additionally, the Radiation Safety Officer estimates that approximately 10% of his time is devoted to reactor activities.

The Radiation Safety Officer reports to the Chairman of the Radiation Safety Committee. This committee is comprised of 15 individuals, mostly faculty, and is currently chaired by the Manager of Environmental Health and Safety.

The Radiation Safety Officer handles personnel monitoring and determines radiation protection policy for all facilities at the University. All personnel with offices in the reactor building and all students with classes in the building are issued personnel dosimeters, about 107 people in total for the academic year 1982. This includes roughly 2 technicians, 2 janitors, 2 secretaries, the director of the reactor facility, the reactor supervisor, 15 faculty members, 4 senior reactor operators, 15 reactor operators, 15 operators in training, and 60 students.

Film is used for dosimetry; it is processed monthly by an outside dosimetry service. The cost is $1/monitor/month. Approximately 20 of the 150 monitors have neutron capability; those cost $4/monitor/month. Extremity monitoring is performed on an ad-hoc basis. On the average, about six ring badges are issued, mostly to the senior reactor operators who pull activated samples out of the pool. Visitors to the facility are issued pocket dosimeters.

A formal bioassay program exists based on action levels. For example, bioassays are performed for individuals handling 1 mCi of iodine, 5 mCi of phosphorous-32 or 15 mCi of tritium in unsealed forms. It is rare at the reactor facility to exceed the action levels; it has not occurred for over a year. The only airborne radionuclides normally encountered at the reactor facility are argon-41 and tritium (in non-detectible concentrations — 10^{-3} to 10^{-5} of the MPC). Whole-body counting has never been performed; every couple of years, an ad-hoc program of urinalysis is conducted.

External exposure distributions for the years 1980 and 1981 are given in the Table. The highest exposures, 0.50 to 0.75 rem, were received in both years by the senior reactor operators who retrieve samples from the pool. The individuals in the range, 0.0 - 0.1 rem, include 60 students in each year. Exposures are maintained relatively low, in part by a restrictive ALARA program, which requires reports by the individual, his supervisor, and the Radiation Safety Officer when an exposure exceeds 0.5 rem for the year. These reports, which are reviewed by the Radiation Safety Committee, are required to explain why the cumulative exposure is so high and what measures are being taken to reduce future exposures.

TABLE

EXTERNAL EXPOSURE DISTRIBUTIONS FOR 1980 AND 1981

Exposure Range (rem)	Numbers of Individuals	
	1980	1981
No Measurable Exposure	45	46
0.0 - 0.1	95	99
0.1 - 0.25	8	2
0.25 - 0.50	2	4
0.50 - 0.75	2	3
0.75 - 1.00	0	0
Greater than 1.00	0	0

An extensive program of instruction is provided in radiation protection principles. The reactor health physicist provides, early in the fall semester, a two-hour orientation to all new students, faculty, and staff members on radiation protection. The University health physics manual and copies of NRC Regulatory Guide 8.13 are distributed, and recipients are required to pass an exam on this material. For the non-technical staff at the reactor facility, this is normally all of the instruction provided in radiation protection principles.

Users of radioactive materials must additionally become certified. There are three levels of certification. For the lowest, or "restricted" level, a ten-hour course in radiation protection principles must be taken, which includes instruction on quantitative levels of risks. The students normally are certified at this level. The next level, denoted as "qualified," contains some use restrictions, and is generally applied to supervisors (faculty, operators, etc.). The highest level is "authorized," contains no use restrictions (other than those imposed by the license), and is generally applied only to the Director of the Reactor Facility. Applicants for certification at the levels of "qualified" and "authorized" must take and pass a full-semester course in health physics.

1. Impact of Reduction in W.B. RPG

There would be no impact on operations at this facility from this change in occupational limits. Limits are currently maintained nearly an order of magnitude lower than the proposed annual limit. Only under a severe accident scenario could exposures be anticipated in excess of 5 rem. Refueling, performed on a 3 to 5 year interval, only exposes personnel to an additional 10 - 15 mrem above normal operational levels.

2. Impact of Reduction in Accumulated Exposure Limit

The maximum accumulated exposure at this facility is believed to be in the range of 5 to 10 rem. On the basis of documented exposures, therefore, there should be no impact from this proposed guidance. There is concern, however, about the undocumented exposures. Sometimes difficulties are encountered in obtaining exposure histories. Several years ago, the University hired a radiation worker with 30 years of experience and no record to document his radiation exposure history. Since the maximum would have to be assumed for this individual (5 rem/yr. after 1960 and 15 rem/yr. before then), he would be unable to obtain a job under this proposed guidance.

It was felt that the 5(N-18) rem limit is more than adequate to protect workers and, therefore, the 100 rem limit is not needed. A proposed alternative approach would be to limit accumulated exposure to "100 rem documented."

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Maximum hand exposures at the facility are on the order of 5 rem/yr., roughly an order of magnitude lower than the revised limit. These exposures are received by operators who retrieve activated samples from the pool. The revised limits to hand and feet, therefore, would have no impact.

Eye lens exposures are not monitored. The only potential for eye lens exposures in excess of W.B. exposures is on the beam port floor. It is believed, however, that annual eye lens exposures, even for beam port experimenters, are considerably lower than 5 rem. Monitoring of eye lens exposures, if required, would be very difficult.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Exposures in excess of 1.5 rem/yr. are not anticipated at the reactor facility. This is corroborated by recent experience, in which the highest annual exposures were in the range of 0.5 to 0.75 rem. Nevertheless, this facility abides by the proposed Range C supervision and monitoring guidance. A health physicist is permanently assigned to the reactor facility. Any time that something is taken out of the pool, the health physicist supervises the activity and performs continuous monitoring.

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

This facility conforms to the proposed guidance of Range B. Every proposed experiment is reviewed by the Reactor Safety Committee. Moreover, as discussed above, this facility currently conforms to the Range C guidance for Range B.

6. Impact of Training Requirements

All new students, faculty, and staff members are given a two-hour orientation early in the fall semester on radiation protection principles by the reactor health physicist. At present, this short course does not include a portion on quantitative levels of risk. To include this, and to update the training manual to this effect, would be a negligible cost at this facility, since the staff and the workers are in the education business.

7. Impact of Guidance for Protection of the Unborn

Approximately 20 percent of those monitored at the reactor facility are female. Under current policy, if a female were to announce a pregnancy (this has never occurred at the reactor facility), she would be removed from exposure situations and would be monitored very closely (with a pocket dosimeter as well as film). If the female were a student, she would probably be allowed to finish the course, but she would be monitored very closely and would be required to file a letter with the University providing her permission for potential exposure. Given the exposure history at the reactor facility, it would not be difficult to maintain exposures to the fetus less than 0.5 rem, even if a pregnant female were permitted to conduct business as usual.

Therefore, this facility is currently operating under a mandatory version of Alternative a. It would not be difficult to amend the existing policy to conform with Alternative b. This would state that a female of child-bearing age could voluntarily decide not to pull samples out of the pool. This is the only activity that could potentially expose the fetus in excess of 0.2 rem/mo. It would not be difficult to accommodate this degree of flexibility, since only about 20 percent of operators are female.

If Alternative c were imposed, women of child-bearing age could not be hired as reactor operators. This would not be an extreme hardship for the facility since only four operators are currently female. However, it would limit the potential sources of support for females.

Some concern was expressed about the ability to estimate the committed dose equivalent to the fetus from radionuclides taken into the body. It is assumed that the NRC would provide some guidance, possibly as a Regulatory Guide, on the calculation of internal exposure to the fetus. In any case, it is unlikely that internal exposures would contribute significantly to fetal exposures at this facility.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

The weighted-organ approach to combining internal and external exposures appears to be sensible. There would be no impact at this facility, since no additional monitoring would be required under normal operations. At present, routine bioassays are performed at the reactor facility.

The Derived Air Concentrations (DAC's) for the radionuclides potentially encountered at the reactor facility, primarily gamma and beta emitters, are largely unchanged under the EPA guidelines. The levels of tritium in the air above the pool are well below the detection limit (8×10^{-7} Ci/ml).

Some concern was expressed about the state-of-the-art for calculating dose from measured organ burdens. Currently, if detectable organ burdens are measured at the University, the results are entered into the records as organ burden, and are not converted to dose. Because of variability between people and uncertainties in the time of exposure, calculation of actual dose is very highly uncertain. The former problem can be dealt with by requiring only dose equivalent to "standard man."

The time problem, however, is difficult to surmount. Some guidelines would be required from the NRC on acceptable methods for converting measured organ burden to dose. A Ph.D. student at the University is looking at this problem for iodine-125. It is estimated that uncertainties as high as 50 - 100% are potentially associated with the conversion to dose from the intake of iodine-125 for specific individuals.

Large uncertainties would also be expected in the conversion to dose for intake of tritium, phosphorous-32, sulfur-35 and carbon -14.

No new software or staff would be required, however, for treatment of internal exposures. Measurable intakes are so infrequent that bioassays could be performed at the Radiation Safety Office. Also, several well-qualified staff and faculty members would be available to estimate the dose.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

A 1.5 rem/yr. limit would have no impact at this facility. Limits are currently maintained nearly an order of magnitude below the proposed 5 rem annual limit. At present, the Radiation Safety Committee must approve exposures in excess of 0.5 rem/yr. As seen in the Table, only a couple of individuals have been exposed in excess of 0.5 rem/yr. over the past two years, and their exposures have been less than 0.75 rem/yr.

K.1. LARGE URANIUM MILL

This facility processes ore received from mines to extract the uranium. The mill, which is about 20 years old, operated continuously (three shifts per day) until recently, but is now running ten days on and four days off. It is shut down for about three weeks once a year for maintenance and for vacations. The mill is designed to process 7,000 tons of ore per day, but it is currently operating at about 50 percent of design capacity. The output of the mill on a full schedule is about 4,300 tons of ammonium diuranate mixed with uranium oxide (yellowcake) per year. The mill utilizes the conventional acid leach-solvent extraction process for uranium recovery. A flow chart of the mill process is shown in the Figure.

The industry currently consists of 20 operating uranium mills, located in western states[1] and accounts for 85% - 90% of natural U_3O_8 production. These mills have a combined rated capacity of about 54,000 tons of ore per day and an output of 21,000 tons per year of yellowcake. Of these mills, 76 percent utilize conventional acid leach - solvent extraction processes, and 10 percent utilize conventional alkaline leach processes.

Although record yellowcake production occurred during 1980, reports for 1981 indicate a decline in production. For calendar year 1982, a greater decrease in production is expected. During 1981, several of the larger mills curtailed their operations, while others either shut down completely or temporarily closed down until such time as demand for yellowcake catches up with supply. It is estimated that the workforce in the industry has been reduced by about 60 percent because of this decreased demand.

The present full time complement of the mill is 250. This includes maintenance personnel (approximately 40). The work force before layoffs was about 1100. All employees except clerical personnel are considered radiation workers. The average annual salary of millworkers is $25,000, including an overhead factor of 35 percent.

Radiation safety is the responsibility of the superintendent of Environment and Industrial Hygiene, who reports to the General Manager. Reporting to the Superin-

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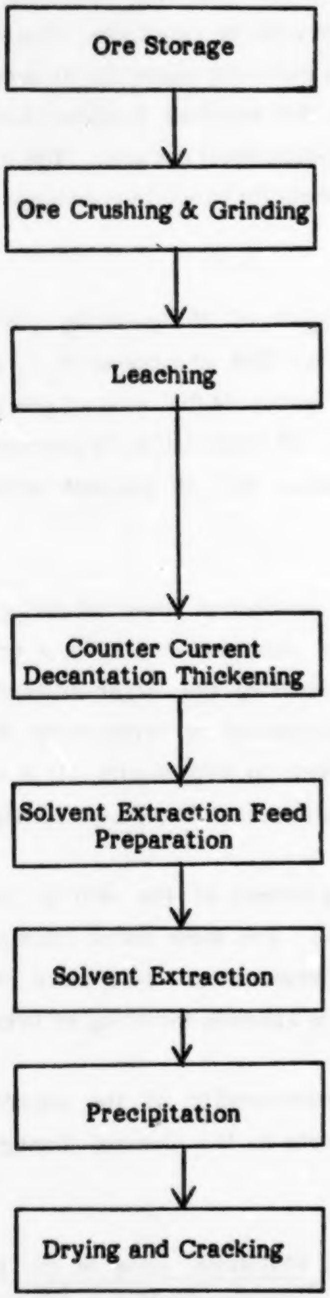
[1] U.S. Department of Energy, Statistical Data of the Uranium Industry, GJO-100(82), Grand Junction Area Office, Colorado, January 1, 1982.

FIGURE

MILL CIRCUIT
CONVENTIONAL ACID LEACH-SOLVENT EXTRACTION PROCESS



Two-stage with decant thickener between stages. Discharge slurry of solids and solution of uranium and concentrated H_2SO_4

2-Series of 6 decantation tanks (known as thickeners)

U_3O_8 Product

tendent is one senior environmental engineer, one environmental technician, and two industrial hygiene and health physics technicians. The technicians in radiation safety are expected to complete a course in radiation protection principles and to attend periodic sessions at the mill on specific safety problems. There is a staff health physicist at the corporate headquarters, who is responsible for providing radiation health and safety standards for all facilities operated by the corporation. The staff health physicist has taken the Health Physics certification examination. Within the corporation there is also a regulation and control group that conducts quarterly audits of the health physics program at each facility. Results of such audits are written up and corrective measures taken, as required, on the basis of the findings.

Potential exists in the mill for both internal exposure from inhalation of uranium and daughter compounds. (U-238, Th-230, Ra-226, Bi-210, Pb-210, and Rn-222 progeny) and external exposure from the low energy gamma rays emitted by these isotopes. There is potential for external exposure in all mill areas except the acid plant. The potential for inhalation is at the crushing circuit, leaching and solvent extraction, and the precipitation and packaging area.

All personnel wear TLD dosimeters to measure exposure from external sources of radiation. Gamma radiation surveys are conducted using calibrated ion chambers or scintillation detectors. Contamination surveys are performed at least quarterly to evaluate the presence and extent of contamination of the surfaces of equipment and buildings. The instruments are capable of selective response to alpha radiation by direct measurement or swipe samples.

Air sampling programs are conducted to determine the airborne concentrations to which employees are exposed. The frequency of air sampling is dependent upon the nature of the work and previous experience with concentrations of airborne radioactive material associated with a particular job. Established operations are sampled on a variable schedule, at least once per week where yellowcake dust is the predominant hazard and weekly where ore dust is the hazard. General air sampling with a permanent multiple-station air sampling system or with continuous air monitors are used for the periodic monitoring of established operations. Sampling for radon daughters is performed biweekly.

The data from the air sampling program are used to calculate the time-weighted average exposure concentration (TWA). The TWA is the sum of the exposure concentrations in the work area multiplied by the length of time that the worker is exposed in each area, divided by the total exposure time. If the calculated exposure is above the radiation protection action limit of 40 MPC-hours/week, the employee is informed, and a urine sample is taken for bioassay. Bioassays at the mill generally follow the procedures described in the NRC Regulatory Guide 8.22. The mill's operating procedure for bioassay of uranium is shown in Table 1.

The average internal and external exposures for routine milling operations in 1979 are given in Table 2. Approximately 3% of those monitored received whole-body exposures in excess of 1.5 rem. The maximum exposure was 2.2 rem. The maximum average annual intake of uranium in 1979 was 0.098 uCi, in the precipitation and packaging areas. The range was 0 to 0.098 uCi for the year 1979. The data for the years 1980 and 1981 are comparable to those for 1979.

The current limit is based upon the MPC for insoluble uranium (1×10^{-10} uCi/ml) multiplied by a 40-hour work week. 100 percent of the employees are within these limits. The average MPC hrs in 1977 were 8 in the YC area, 18 in the crushing circuit, and 14 in the bucking room. All operators work the same position and get the same exposure. These numbers are based upon the conservative assumptions of insoluble natural uranium, totally respirable particle size distribution, and no respiratory protection.

All new employees are required to attend a 24-hour training program. This program includes three hours of training on the principles of radiation protection, followed by an examination. The session does not include a discussion of quantitative levels of risk; however, it is expected to be included in the near future. Special attention is given to female employees. Each female is given a copy of Regulatory Guide 8.13 and is expected to read it and understand its contents. Periodic review sessions are conducted as part of industrial safety training to review all rules and regulations and to promote good working habits and awareness of safety procedures. Every year, an eight hour refresher training course is conducted for all employees, which includes 1½ hours of instruction in radiation safety.

TABLE 1:

BIOASSAY FOR URANIUM

INTERNAL

Internal exposure from uranium may be determined from urine sample results. Routine samples are collected from persons working in the yellowcake process and packing areas biweekly after periods of at least twenty-four hours away from the facility. Urine samples are given at the person's home to avoid contamination. Standard fluorimetric assay techniques are used for sample analysis. Pre-assignment and termination samples are collected and analyzed.

Additional special samples are collected and analyzed after suspect or known accidental exposures to excessive airborne uranium concentrations.

URINE ACTION LEVELS

Action levels are established for single biweekly samples for the purpose of controlling kidney and bone exposure in cases of soluble uranium and lung exposure in cases involving inhalation of insoluble uranium.

Routine samples are collected after a worker has been out of the plant for at least 24 hours. These are voidings of about 150 mℓ in 6 oz. bottles.

Any employee submitting two consecutive biweekly routine or special samples above 150 μg/ℓ shall be promptly restricted to non-uranium work. Daily samples shall then be analyzed until a sample result below 50 μg/ℓ is received at which time the employee may be removed from work restriction.

An employee who submits four consecutive biweekly samples which are all analysed to be less than 150 μg/ℓ but greater than 50 μg/ℓ shall be promptly placed on a "24-hour equivalent" sampling schedule. The schedule is performed as follows:

(a) A quart-size sample bottle is supplied to the employee for at-home urine sample collection.

(b) The employee collects a voiding before retiring, any voiding during the night, and any voiding the morning after. He returns the bottle on his next work shift.

Should the 24-hour equivalent sample analysis be greater than 50 μg/ℓ, the employee is restricted to non-uranium work. He is resampled at least weekly. Whenever the employee's sample analysis returns to below 50 μg/ℓ, he may then resume uranium work.

TABLE 2:

AVERAGE INTERNAL INTAKE AND EXTERNAL EXPOSURES FOR ROUTINE MILLING OPERATIONS IN 1979

	INTERNAL		EXTERNAL
MILL AREA	Uranium Ore Dust* (dpm/liter)	Intake** (uCi)	(rem)
Crushing Circuit	0.050	0.054	0.29
Bucking Room	0.078	0.084	0.32
Leaching & Solvent Extraction	—	—	0.50
Precipitation & Packaging Areas	0.091	0.098	1.62

*Current limit is 0.22 dpm/liter.
**Current limit is 1.35 µCi for D solubility and 0.81 µCi for W solubility.

1. Impact of Reduction in W.B. RPG

This limit is not expected to have an impact at the mill, at least with respect to external exposure. The highest whole body exposure in 1979 was 2.2 rem. The maximum average external exposure was 1.62 rem, in the precipitation and packaging area.

2. Impact of Reduction in Accumulated Exposure Limit

The reduction of the accumulated exposure limit to 100 rem is not expected to have a cost impact at this mill. The highest accumulated exposure for mill personnel is well below this limit.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

No impact is expected from the revised extremity limits. There are potential exposures of the extremities (hands and skin) for the scrap pickers, where the dose rate is about 3 mrem/hr. There are 6-8 employees in this work area. However, even for continuous work in this area, annual exposures are expected to be less than 10 percent of the proposed limit. The eye lenses of employees are not expected to be exposed to higher levels than the whole body.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

The average annual internal exposure in the precipitation and packaging area is 1.62 rem. All other areas are less than 1.5 rem. About three percent of those monitored receive whole body exposures in excess of 1.5 rem. The main impact from the proposed guideline would be due to the new internal exposure RPG. As noted in Table 2, the solubility class for the Derived Air Concentrations for uranium inhalation is a critical parameter for compliance. If the new guidelines on internal exposures are imposed it would be difficult to maintain combined exposures below 30 percent of the RPG. The difficulty in meeting the new RPG is discussed later in this case study.

Potential internal exposures are monitored with a multiple air sampling system and external exposures for all personnel are measured with TLD dosimeters. One senior environmental engineer, one environmental technician and two industrial hygiene and health physics technicians provide radiation protection services. It is anticipated that a certified health physicist at a cost of $40,000 per year would have to be employed in the precipitation and packaging area to comply with the proposed Range C guidance.

5. Impact of Proposed Guidance for Potential Exposure in the Range of 0.1 to 0.3 RPG

The mill is currently operating in full compliance with this proposed guideline. All personnel wear TLD dosimeters to measure external exposures. Potential internal exposures are monitored with a multiple air sampling system. One senior environmental engineer and two industrial hygiene and health physics technicians maintain records on external sources of radiation and airborne concentrations at the four mill operating areas, review health physics procedures and are available to monitor during non-routine operations. These professionals are expected to assure that exposures are justified and are ALARA.

6. Impact of Training Requirement

There would be no impact from the training requirements of the proposed guidelines, since all new employees receive instruction in radiation protection principles (a unit on levels of risk to be added in the near future).

7. Impact of Guidance for Protection of the Unborn

Approximately eight percent of the mill personnel are currently females of child-bearing age. There would be no impact from Alternative a of the proposed Guidance for Protection of the unborn, since the present corporate policy follows NRC Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure." Women are instructed to inform their supervisors when they are diagnosed to be pregnant. As soon as the supervisor is notified, the woman is removed from the job and is assigned to a job in a non-controlled area. Alternatives b and c might result in women being denied certain jobs.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

The current approach at this mill is to conduct complete surveys of all locations on a weekly basis. Compliance with existing guidance on internal exposures is determined by calculating potential exposures to airborne concentrations of uranium from airborne monitoring data plus time and area assignments for each worker. From these data, a time-weighted average exposure (TWA) of an individual is determined which is reported as a fraction of the MPC. Internal doses are not calculated unless the calculated airborne exposure is greater than 40 MPC-hrs/week for soluble uranium and 520 MPC-hrs/qtr. for insoluble uranium. These exposures to soluble uranium are verified, using the bioassay procedures described earlier. Although airborne exposure calculations predict higher exposures than the individual actually receives, they are used as the dose of record since the data are more timely than bioassay results. External exposures obtained from TLD readings are not presently added to estimated internal doses. A computer program at the mill is currently in place which provides data for determining compliance with the existing regulations.

Reference to Table 2 indicates that the current average intakes in most areas are higher than the Allowable Limit of Intake (ALI) prescribed by ICRP-30 for insoluble (Class Y) uranium — 0.054 uCi. Therefore, in order to comply with the new limits, the conservative assumption of total insolubility would have to be relaxed. The DAC for soluble uranium (Class D) is a factor of about 30 higher than that for insoluble uranium (Class Y). It is estimated that using actual solubility fraction would lower the calculated exposure by a factor of about 15. (Recent measurements indicate 60% Class D and 40% Class W.) The justification for this relaxation would require continual determination of the actual solubility fractions in the mill process areas.

Establishment of routine system for measuring solubility fractions would take a professional approximately 6 man-months of effort (at a cost of approximately $3,800 per man-month). Then routine monitoring of this parameter is expected to take a technician approximately 10 man-days each month. (It is assumed that the NRC would require continual routine monitoring of this parameter.) The one time equipment cost for solubility fraction sampling is estimated to be approximately $22,000. Additionally, laboratory support is estimated to cost approximately $30,000 per year.

Particle size determinations would also have to be made at approximately 10 locations for a one-time equipment cost of $20,000 and an analytical cost of $2,000/yr. Also, in order to provide adequate personnel monitoring, an additional number of personal sampling pump assemblies would be required at a cost of $9,000. Finally, all particulate air samples will have to be analyzed for isotopic content. This is estimated to cost $192,500 per year.

The computer software and hardware used for the evaluation of personnel exposures would also have to be upgraded. It is estimated that to modify the software, approximately 6 man-months of a programmer would be required. Hardware costs of $30,000 are estimated. Additionally, a full-time records clerk would have to be employed at an annual cost of $16,200.

It is expected that the effect of the above exposure procedures would be to demonstrate compliance with the ICRP-30 limits. However, the proposed EPA limits are about another 30-40 percent lower. At present, it is not certain that these changes will bring calculated potential exposures down to the proposed EPA levels.

The weighted organ doses in the proposed guidelines are viewed as a potential problem area, since they appear to be in conflict with ICRP 26 and 30.

9. Impact of the Reduction of the W.B. RPG to 1.5 rem/yr.

The imposition of this alternative RPG would have a cost impact on the mill operations, particularly in light of the reduced intake limits. It is reasonable to conclude that there would be a problem in the precipitation and packaging area. In order to meet the guideline it would probably require a process change; i.e., a change to a slurry process. Moreover, it would possibly require additional people for health physics protection and to demonstrate compliance with the guidance.

K.2. URANIUM CONVERSION PLANT

This plant produces uranium hexafluoride (UF_6) at a rated output of 10,000 MT/yr. and employs 160 people. The plant operates three shifts per day, seven days per week. The raw material is uranium concentrate (yellowcake) and some yellowcake slurry received from all uranium mills in the country. At present there is only one other conversion plant in operation, with a rated output of 14,000 MT/yr. of UF_6. Both plants, due to the reduced demand for uranium in the nuclear power industry, are currently operating at reduced capacity.

This conversion plant utilizes a complex wet chemistry process, whereas the other plant utilizes a dry process. The yellowcake at this plant starts at the sampling plant and is processed by stages through digestion, solvent extraction, denitrification, reduction, hydrofluorination, fluorination, and in the final stage to a primary cold trap that is heated with steam to 200 F^o at 200 psi. At this point, the the UF_6 is a liquid and is drained to shipping cylinders that hold 10 tons. Workers at the plant are potentially exposed to both soluble (uranium hexafluoride, uranium trioxide, uranyl oxyfluoride, and uranyl nitrate) and less soluble (uranium tetrafluoride and uranium dioxides) compounds of uranium.

Radiation safety is the responsibility of the manager, Health Physics and Industrial Safety, who reports to the Plant Manager. Five health physics technicians, and one clerk report to the Manager, Health Physics and Industrial Safety. The technicians in Radiation Safety are expected to complete a course in radiation protection principles. The annual health physics cost at the plant is approximately $181,000. There is a staff health physicist at corporate headquarters who is responsible for providing radiation health and physics standards for facilities operated by the corporation. He has taken the health physics certification examination. Within the corporation there is also a regulatory compliance group that conducts quarterly audits of the health physics program at each facility. Results of such audits are written up and corrective measures taken, as required on the basis of the findings.

Potential exists in the plant for both internal exposure from inhalation of uranium and daughter compounds and external exposure from low energy gamma rays emitted by these isotopes. There is potential for external exposure in all plant processing areas, with the highest radiation fields in the fluorination area, 90 mrem/hr. and 20 mrem/hr. in 1980 and 1981, respectively. There is potential for inhalation in all plant processing areas, with monthly average concentrations in 1981 ranging from 0.08 MPC to 0.36 MPC. Normally, people are in these areas four to six hours per shift.

Air sampling is extensive throughout the plant. There are 45 sampler heads in dry process areas that are connected to a central vacuum. The filters are changed after each eight-hour shift. Air samples reading above 0.5 MPC are considered facility action levels and are reported to corporate management. Additionally, depending upon working conditions, breathing zone air samples, and operational air samples are collected weekly. Internal exposures are evaluated daily for each person by calculating the time-weighted average exposure concentrations (TWA), based on the air sampling results and work location. The TWA is the sum of the exposure concentrations in each work area multiplied by the time that the worker is exposed, divided by the total exposure time.

The internal bioassay and in-vivo counting policy for uranium (except UF_6 and UO_2F_2) is described in Table 1. The bioassay policy for UF_6 and UO_2F_2 is described separately in Table 2. Fecal sampling procedures for early assessment of uranium and thorium exposures are included in the radiation protection procedures and samples are taken as determined from air sample results.

The results of the bioassay program in 1981 gave uranium concentrations in urine ranging from a minimum of 2 ug/l to a maximum of 51 ug/l.

Whole-body counting is done by an outside contractor. The results of whole-body counting in 1981 are given in Table 3.

Airborne concentrations in each plant area for the years 1979, 1980 and 1981, expressed in fractions of MPC, are given in Table 4. These also correspond to annual average personnel exposures to airborne concentrations because personnel do not ordinarily divide their time between areas. At any one time, airborne concentrations may go as high as 30 times MPC (from incidents).

The current limit is based on the MPC for insoluble uranium (1×10^{-10} uCi/ml), multiplied by a 40-hour work week. One hundred percent of the employees have been

TABLE 1

URINALYSIS & IN VIVO COUNTING
BIOASSAY FOR URANIUM
(Except UF_6)

Internal

Internal exposures from uranium are determined from urine sample results. Routine samples are collected from persons working in the process area on a bi-monthly frequency after periods of at least twenty-four hours away from the facility. Pre-employment and termination samples are collected and analyzed.

Additional special samples are collected and analyzed after suspect or known accidental exposures to excessive airborne uranium concentrations.

Urine Action Levels

Action levels are established for single bi-weekly samples for the purpose of controlling kidney and bone exposure in cases of soluble Class D uranium and lung exposure in cases involving inhalation of the less soluble Class W uranium.

Routine samples are collected after a worker has been out of the plant for at least 24 hours.

Any employee submitting a routine sample or a special sample (known to be non-transportable uranium) above 100 ug/l will be placed on immediate work restriction. Upon receiving a 100 ug/l sample result, resampling will be done daily until a sample result below 20 ug/l is received and the employee can be removed from work restriction.

When an employee submits a routine sample $<$ 20 ug U/1, he is promptly given a take-home sample bottle. He collects a voiding at home and returns the bottle on his next work shift. Should this second sample be $>$ 20 ug U/1, he is assigned to non-uranium work. He is resampled daily until a sample shows $<$ 20 ug U/l, after which he may return to his regular work assignments.

Whole Body Counting

In-Vivo (lung) counting to detect internal deposition is performed annually for employees who fall under one of the following categories:

- Routine analysis shows consistly elevated uranium-in-urine concentration (above the 20 ug/l guideline.)
- Exposure to uranium aerosols which are insoluble in body fluids.
- Exhibit a lung burden $>$ 30 percent of the allowable committed dose equivalent
- Previous lung counting history shows a significant fraction of body burden of natural uranium or U-235.

All other employees who normally work in radiation areas are counted every two years.

TABLE 2

BIOASSAY FOR UF_6 AND UO_2F_2

The uranium in UF_6 and UO_2F_2 exhibits a very rapid urinary excretion half time. The model for standard man indicates an elimination half time of six hours. For different individuals it is not unusual to have half times of four hours to seven hours. Accordingly, urine samples must be obtained within a few hours of such an intake. The appropriate sampling program shall be selected as given below:

Time of Intake Known and Recorded - (Spills and High Airborne Concentrations)

1. Each exposed individual should empty his/her bladder and discard this urine as soon after the exposure as possible but in no case longer than 30 minutes after the exposure. Do not void again until step 2 below.

2. The first single urine sample shall be collected three (3) to six (6) hours after the exposure. The voiding time shall be recorded on bottle No. 1.

3. The next voiding from about 6-10 hours after the exposure does not need to be collected.

4. Collect the following single urine sample 10 to 15 hours after the exposure. Record the voiding time on bottle No. 2.

5. If the voiding collection in step 4 is missed, be sure to collect the next voiding no later than 20 hours after the exposure. Record the voiding time.

6. The analysis results of the two samples collected are reported in ug/l. Plot these values vs. hours on semi-log paper and extropolate back to the end of the exposure where the time is zero hours. Determine the 4-hour intercept on the line draw on the semi-log paper and calculate the intake as follows:

$$I = 1.32C$$

Where: I = Intake in micrograms of uranium

C = Concentration of uranium in urine (ug/l) at 4 hours after the end of the exposure as determined from the plot on the semi-log paper.

$1.32 = \frac{2500}{1900}$, where 2500 micrograms of uranium intake results in a concentration of 1900 ug/l of uranium in the total urine excreted for four hours after a UF_6 inhalation exposure by a "standard" man.

TABLE 2 (CONT.)

7. The MPC-hr exposure estimate is calculated as follows:

$$\frac{\text{1 x 40 MPC - hrs.}}{\text{48 M}^3 \text{ x 200 ug/M}^3} = \text{MPC - hrs.}$$

Where: I = ug intake

48 M^3 = air breathed at work for 40 hours

200 ug/M^3 = 0.2 mg/M^3 = 1 MPC (see footnote No. 4 to Appendix B of 10 CFR 20).

TABLE 3

IN-VIVO (LUNG) COUNTING[1]

Plant Area	No. of Employees Counted	1981 In-Vivo Counting Range of Results	
		ug U-235	nCi U(nat.)
Sampling Plant Operators	1	0.0 ± 29	1.5 ± 1.0
Processing Personnel	29	0.0 ± 28 to 47 ± 39	1.4 ± 1.0 to 8.2 ± 1.6
Maintenance Personnel	23	0.0 ± 33 to 0.0 ± 46	0.0 ± 1.1 to 11.5 ± 1.5
Other Personnel	15	0.0 ± 31 to 0.0 ± 57	1.3 ± 1.1 to 4.5 ± 1.2

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[1] The analysis for U-235 is the least reliable when the lung burden is $<$100 ugms U-235 (γ at 186 KeV). The MPLB for U (nat) is 180 ugm U-235 or 25.35 mgm U (nat).

TABLE 4

ANNUAL AVERAGE AIRBORNE CONCENTRATIONS
FRACTIONS OF MPC*

Operating Area(s)	No. of Sample Locations	1979	1980	1981
Sampling Plant	5	.26	.26	.14
Digestion	4	.18	.28	.23
Denitration	6	.35	.41	.15
Reduction and Hydrofluorination	11	.42	.55	.18
Fluorination	11	.26	.39	.17
Misc. Areas	8	.07	.11	.05

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*MPC = $1 \times 10^{-10} \frac{uCi}{ml}$

within this limit. The new Derived Air Concentration for insoluble uranium is approximately 2×10^{-11} uCi/ml and the DAC for soluble uranium is 6×10^{-10} μCi/ml.

The current Maximum Permissible Concentration (MPC) for occupational exposure to Th-230 is 2×10^{-12} uCi/ml for soluble material and 1×10^{-11} uCi/ml for insoluble. An airborne aerosol of raffinate solids is the most likely source of the radionuclide Th-230. If the dried product has Class W solubility, then the bone will be the primary organ at risk. If it has Class Y solubility, then the lung will be the primary organ at risk.

All personnel except clerical workers wear film badges to monitor external exposures to radiation. Film badges are processed monthly by an outside dosimetry service.

The measured whole-body exposures for the years 1979, 1980, and 1981 are given in Table 5. Radiation levels in plant areas are also measured by ionization chambers. General area surveys are made monthly at fixed work stations, particularly the fluorination ash receiver area. This area is usually designated as a radiation area (in excess of 5 mrem/hr). However, the surface contact of filled ash containers could be as high as 100 mrem/hr. Gamma surveys in plant areas for 1981 showed that the fluorination area had the highest dose rates — 1 to 20 mr/hr. Contamination surveys are performed at least weekly to evaluate the presence and extent of smearable contamination on the surfaces of equipment and buildings.

All new employees are required to attend a 1½ hour orientation training program. Individuals assigned to work with uranium receive at least eight hours of formal training on the hazards associated with the handling of uranium, the procedures for radiation protection, safety procedures, and government rules and regulations. Included in the training for all employees is the subject matter in Regulatory Guide 8.29, "Instruction Concerning Risk from Occupational Exposures," and for female employees, the subject matter contained in Regulatory Guide 8.13, "Instruction Concerning Prenatal Exposure." A discussion of the quantitative levels of risk is not presently included in the training but is expected to be included in the very near future.

A written examination demonstrating that the employee has a good understanding of the training subjects is given to each employee. "Tailgate" safety meetings are conducted monthly by line supervisors. Employees that are required to wear respiratory protection devices are given 1½ hours of special training on the use of the devices and

TABLE 5

WHOLE-BODY EXPOSURES

Annual Dose Ranges (Rem)	Numbers of Individuals In Each Range		
	1979	1980	1981
Minimal Exposure	8	10	23
Measurable Exposure < 0.10	57	88	89
.10 to .249	52	35	42
.250 to .499	33	38	23
.500 to .749	4	8	4
.750 to .999	2	1	1
1.00 to 1.99	0	1	0
2.00 to 2.99	0	0	0
3.00 to 3.99	0	0	0
4.00 to 4.99	0	0	0
Greater than 5.00	0	0	0
Totals	156	181	182

the plant conditions for which these devices are required. Every year an eight hour refresher training course is conducted for all employees and this includes approximately two hours devoted to radiation protection.

1. Impact of Reduction in W.B. RPG

This revised limit is not expected to have an impact at the plant, at least with respect to external exposures. The highest whole-body exposure in 1981 was less than one rem.

2. Impact of Reduction in Accumulated Exposure Limit

The reduction of the accumulated exposure limit to 100 rem is not expected to have a cost impact at this plant. The highest accumulated exposure for plant personnel is considerably lower than the 100 rem limit.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

No impact is expected from the revised extremity limits.

4. Impact of Proposed Guidance for Potential Exposure in the Range of 0.3 to 1.0 RPG

The whole body exposures of all plant personnel have been maintained at less than 1.0 rem for the years 1979, 1980, and 1981, except for one employee in 1980. The main impact from the proposed guideline would be due to the new internal exposure RPG. Some plant workers would be potentially exposed to airborne concentrations in excess of the revised insoluble uranium limit (RPG $1x10^{-11}$ uCi/me). As presented in Table 4, the average annual exposures in each of the five process areas would range from 1.4 to 2.3 times the insoluble uranium RPG for the year 1981. If the new guidance on internal exposures were to be imposed, it would be difficult to maintain combined exposures below 30 percent of the RPG. The difficulty in meeting the new RPG is discussed in item 8 of this case study.

Potential internal exposures are monitored by means of an extensive air sampling system in which 45 sampler heads are connected to a central vacuum and the filters changed after each eight-hour shift. The manager of Health Physics and Industrial Safety and five health physics technicians provide radiation protection services at the plant. It is anticipated that a certified health physicist, at a cost of $40,000 per year, would have to be employed to provide radiation protection, supervision in the plant areas in order to comply with the proposed Range C guidance.

5. Impact of Proposed Guidance for Potential Exposures in the Range O.1 to 0.3 RPG

The plant is currently operating in full compliance with this proposed guidance. All personnel wear film badges to measure external exposures. Potential internal exposures are monitored with an extensive air sampling system. The manager of Health Physics and Industrial Safety and five health physics technicians maintain records on external sources of radiation and airborne concentrations in the six plant areas, and are available to monitor during non-routine operations. These professionals are expected to assure that exposures are justified and are ALARA.

6. Impact of Training Requirement

The existing training program satisfies the proposed guidance on training.

7. Impact of the Guidance for Protection of the Unborn

At present, approximately 19 percent of the plant employees are females of child-bearing age. Presently the corporation management conforms to the policy as described in Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure." Accordingly, there is not expected to be a cost impact from Alternative a of the guidance for protection of the unborn. The proposed Alternative b is not considered to be a viable alternative at this plant since pregnant women are assigned to non-radiation areas. Alternative c might result in women not being considered for certain jobs.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

The current approach is to calculate time-weighted average exposure concentrations (TWA) based on measured airborne concentrations of uranium and work location cards.

The TWA is calculated for each person that routinely works in a process area and is recorded as a fraction of the MPC. Internal doses are not estimated unless the calculated airborne exposure is greater than 40 MPC-hrs/week for soluble uranium and 520 MPC-hrs/qtr. for insoluble uranium. These exposures are verified using the bioassay procedures described earlier and the results are recorded along with MPC-hrs. Measured external exposures obtained from the film badge readings are not currently added to the estimated internal exposures. A computer program at the plant is currently in place which provides output data for determing compliance with the existing 10CFR20.

As can be seen from the data presented in Table 4, some of the plant workers would be potentially exposed to airborne concentrations in excess of the revised insoluble uranium limit (DAC of 2×10^{-11} μCi/ml). For 1981, the average annual personnel exposures in each of the five process areas would range from approximately 0.7 to 1.2 times the insoluble uranium DAC. The approach to compliance with the revised limits would be essentially the same as at present, namely calculation of potential exposure to uranium for each worker using the TWA method. However, the conservative assumptions currently made would have to be relaxed. In particular, measured particle sizes and solubilities would be used in the calculations.

Particle size distributions in air are presently not available for the facility. It is estimated that using actual measured particle size distributions would reduce calculated potential exposures by about 20 to 30 percent. Larger gains are potentially available from the use of measured solubility factors.

Determination of actual solubility fractions could lead to the relaxation of the conservative assumption of total insolubility (Class Y). The MPC's for soluble uranium are a factor of about 30 higher than those of insoluble uranium. It is estimated that using actual solubility class (i.e., Class W solubility) would lower the calculated potential exposures by about a factor of fifteen (i.e., Class Y to Class W).

Establishment of a routine system for measuring solubility fractions would take a professional approximately six man-months of effort (at a cost of approximately $3800 per man-month). Then routine monitoring of this parameter is expected to take a technician approximately 10 man-days each month. (It is assumed that NRC I&E would require continual routine monitoring of these parameters.) The one-time equipment costs for sampling of solubility class are estimated to be approximately $22,000. Additionally, laboratory support for determination of solubility fractions is estimated to cost approximately $30,000 per year.

Particle size determinations would also have to be made at approximately 10 locations for a one-time equipment cost of $20,000 and an analytical cost of $2,000/yr. Also, in order to provide adequate personnel monitoring, an additional number of personal sampling pump assemblies would be required at a cost of $9,000. Finally, all particulate air samples will have to be analyzed for isotopic content. This is estimated to cost $192,500 per year.

The computer software and hardware used for the evaluation of personnel exposures would also have to be upgraded. It is estimated that to modify the software, approximately six man-months of a programmer would be required. Hardware costs of $30,000 are estimated. Additionally, a full-time records clerk would have to be employed at an annual cost of $16,200.

It is expected that the effect of the above internal exposure procedures would be to demonstrate compliance with the ICRP-30 limits. However, the proposed EPA limits are about another 30-40 percent lower. At present, it is not certain that these changes will bring calculated potential exposures down to the proposed EPA limits.

The weighted organ doses in the proposed guidelines are viewed as a potential problem area since they appear to be in conflict with ICRP 26 and 30.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

The imposition of this alternative RPG would have a cost impact on the conversion plant operations, given the parallel imposition of the reduced intake limits. There would probably have to be process changes and/or increased confinement on certain operations. Moreover, considerably more effort would have to be expended on this radiation protection program.

L. NUCLEAR PHARMACY

With gross sales of $30M annually, this nuclear pharmacy has approximately 50 percent of the market for radiopharmaceuticals supplied out-of-house. (Roughly 50 percent of the unit dosages used in nuclear medicine are made up in-house.) Another large nuclear pharmacy has most of the remaining market, and four small firms have less than 10 percent of the market.

The firm is comprised of approximately 30 operational pharmacies located in separate cities throughout the U.S., mostly in non-Agreement States. A typical pharmacy employs three pharmacists, one nuclear medicine technologist, a secretary, and 10 delivery personnel. Additionally, a salesman services four pharmacies. The firm has a total of about 500 employees.

Ninety percent of the radiopharmaceuticals consist of Tc-99m (eluted from a molybdenum generator) or Tc-99m — tagged compounds. Most of the remainder are either iodine-131 or xenon-133. A smattering of Tl-201, Ga-67, I-123, Yb-169, Cr-151, and In-111 is also handled. A typical pharmacy handles approximately five Curies per day of Tc-99m and roughly 200 mCi of the others.

Personnel dosimeters (film) are provided to all employees. Dosimetry is performed by an outside service and whole-body badges are read monthly at a cost of $.70/badge/month. Additionally, approximately 380 workers are provided extremity monitors (ring badges). Of these, approximately 100 (for the dispensers — largely the pharmacists) are read weekly and the remainder (for the handlers — largely the drivers) are read monthly. A few people wear wrist badges in addition to ring badges.

Whole-body exposures are relatively low. Of the hundred or so dispensers who receive measurable doses, the average is less than 500 mrem/yr. and the maximum is less than 1 rem/yr. The W.B. exposures of the handlers is insignificant.

The average hand exposure during a recent quarter was about 2.8 rem. Thirteen individuals exceeded 4.75 rem hand exposure during the same quarter. The maximum hand exposure was roughly 9 rem.

Bioassays, in accordance with NRC Regulatory Guide 8.23, are performed routinely on all individuals who handle I-131. Both urinalyses and thyroid monitoring are done. Initially, thyroid monitoring is performed bi-monthly. If nothing is detected, the frequency is reduced to quarterly. Urinalyses are routinely performed monthly.

Air sampling is additionally performed at some of the facilities. Typically one sampler is set up and counts are taken at the end of the day. The existence of the air sampler at a facility has historical, rather than health physics significance. Eventually, these air samplers may be eliminated if compliance can be demonstrated by calculation.

In 1981, the maximum thyroid burden of those monitored was .06 μCi or approximately 40% of the limit. Most individuals had no measurable thyroid burden. Moreover, radioiodine was not detected in anyone's urine.

This nuclear pharmacy is one of two wholly-owned subsidiaries of a parent organization. The complete health physics organization is situated in the parallel subsidiary, and the Corporate Radiation Safety Officer reports to the president of this subsidiary, who in turn reports to the president of the corporation. A generic health physics program is established by the corporate health physics group for each pharmacy. This program includes a safety manual and procedures, and periodic audits. Additionally, the personnel monitoring program is run out of the corporate office.

At the local level, each pharmacy has a Radiation Safety Officer (usually a pharmacist) who reports on radiation safety matters to the Corporate Radiation Safety Officer. Typically, the local RSO spends approximately 10 percent of his time on matters relating to radiation safety.

The corporate RSO has approximately 20 years of experience as a radiological physicist at a hospital. His academic background is radiation biophysics. The backgrounds of the other three individuals comprising the corporate health physics staff are also in nuclear medicine rather than health physics. However, it is felt that the experience of all four individuals renders them equivalent to radiation protection professionals (i.e., health physicists).

A radiation protection instructional program is in the developmental stage. This is an audio-visual program directed to both dispensers and handlers. The core of this program will be presented to an individual before he starts work, with an update annually. He will be required to pass an examination on the material, which includes a section on quantitative levels of risk from radiation exposure.

1. Impact of Reduction in W.B. RPG

In 1981, the highest whole-body exposure was less than one rem. The average whole-body exposure was 0.5 rem. Thus, the imposition of a 5 rem annual limit would not impose a burden on this firm.

2. Impact of Reduction in Accumulated Exposure Limit

There are probably no employees with lifetime exposures exceeding 5 rem. This proposed guideline would have no impact for this firm.

3. Impact of Proposed Guidance Relative to Extremities and Individual Organs

Skin and eye lens doses are comparable to whole-body doses. However, hand exposures, by virtue of the nature of the work performed by the dispensers, are relatively high. Accordingly, the reduced hand limits (from 75 rem/yr. to 50 rem/yr.) could be a problem for selected individuals. For example, one individual exceeded 50% of the hand exposure limit last quarter. This same individual generally averages 13 rem/qtr. Most individuals average approximately 1 rem/month.

Hand exposures should be able to be maintained well below 50 rem/yr. The problem with the few-outliers is technique, and this should be able to be remedied with a little attention from the corporate health physics staff. Currently, an administrative limit of 1 rem/wk. is in effect. If the revised extremity limits were to be promulgated, an administrative limit of approximately 3 rem/mo. would be adopted. The costs of complying with the revised hand limit should be minimal.

There may actually be a cost benefit from the new extremity limits. Presently, the cost of personnel monitoring is $36,000 yr. Approximately $9,000 of this is from the weekly hand monitoring of 100 employees ($1.72/badge/week). If the quarterly limit were dropped, monthly monitoring should suffice, providing a cost savings of approximately $7,000. Also, the annual costs for analysis of exposure data is estimated to be approximately $15,000. This would be reduced by approximately 50 percent if weekly monitoring were dropped.

4. Impact of Proposed Guidance for Potential Exposures in the Range of 0.3 to 1.0 RPG

Exposures in excess of 0.3 times an RPG are only possibly anticipated for the hands (greater than 15 rem/yr.). At present, the average annual exposure to the hands is 12 rem/yr. High doses to the hands are obtained by the dispensers who "pull doses." However, full-time supervision and monitoring by a radiation protection professional would not be required under the proposed guidelines because there is no single task in which the contribution to the annual exposure is "significant."

5. Impact of Proposed Guidance for Potential Exposures in the Range of 0.1 to 0.3 RPG

The guidance for exposures in the range of 0.1 to 0.3 RPG describes the existing program. Thus, there would be no impact from this guidance.

6. Impact of Training Requirements

The training program which is currently under development by the company satisfies the proposed guidance. By the time that the guidelines are formally proposed, this training program will be well under way.

7. Impact of Guidance for Protection of the Unborn

Approximately five percent of the dispensers and handlers are female. All female employees are required to read NRC Regulatory Guide 8.13. As of yet, however, there has not been a pregnant pharmacist. If there were, she would probably be asked to take a leave of absence. Exposures to the fetus could probably be maintained below 500 mrem, but it would be too risk. If a handler were to become pregnant, she would be kept out of the restricted area (no packing, just delivering). Whole-body exposures to deliverers can easily be kept below 500 mrem over a nine-month period. Therefore, the firm is currently operating under a mandatory version of Alternative a.

It is possible, though unlikely, for a worker to receive a W.B. exposure in excess of 0.2 rem/mo. who milks generators or compounds radiopharmaceuticals. Thus, if Alternatives b or c were to be promulgated, women of child-bearing ages would be precluded from doing these jobs. However, there are currently only about six women in the company who perform these jobs. Thus the impact on the firm would be inconsequential. However, these alternatives would pose substantial EEO problems.

8. Impact of the Internal Exposure and Combined External Exposure Guidance

The two radioisotopes of concern from an internal exposure perspective are iodine-131 and xenon-133. Intakes of these isotopes are currently a very small fraction of the proposed RIF's.

If the proposed internal exposure guidance were to be promulgated, no additional monitoring is expected to be required. However, the existing software would have to be modified to convert the measurements to dose and to add the weighted organ dose to the external exposure. It is estimated that the cost to develop the additional software is approximately $15,000. Moreover, the operating costs for the dose tracking system, currently at approximately $30,000/yr., would be increased by an estimated 30 percent, or approximately $9,000/yr.

9. Impact of the Reduction of the W.B. RPG to 1.5 Rem/yr.

The firm could operate within a 1.5 rem/yr. W.B. exposure limit with little or no impact.